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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 158

A. D. MELVIN, CHIEF OF BUREAU-

THE ROUNDWORMS OF DOMESTIC SWINE, WITH SPECIAL REFERENCE TO TWO SPECIES PARASITIC IN THE STOMACH.

MACH.
UNIVERSITY OF CALIFORNIA
AT LOS ANGELES

BY

WINTHROP D. FOSTER,
Junior Zoologist, Zoological Division



WASHINGTON:
GOVERNMENT PRINTING OFFICE

1012





Haines, del.

BREWER & KESSLER, DELA.

A PORTION OF THE PYLORIC END OF A HOG'S STOMACH, INFESTED WITH ARDUENNA STRONGYLINA AND PHYSOCEPHALUS SEXALATUS. (NATURAL SIZE.)

The worms appear as fine red lines partly buried in a yellow glairy mass of necrotic tissue. Ulcers are found underneath this necrotic tissue.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., July 2, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "The Roundworms of Domestic Swine, with Special Reference to Two Species Parasitic in the Stomach," by Mr. W. D. Foster, of the Zoological Division of this bureau. I respectfully recommend its publication in the bulletin series of the bureau.

The paper deals particularly with two species of nematodes which have recently attracted considerable attention in connection with the Federal meat inspection. The parasites are shown to be of wide distribution and frequency of occurrence in American swine, and they are a source of possible serious injury to these animals.

The illustrations were drawn by Mr. W. S. D. Haines, of this bureau.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE ROUNDWORMS OF DOMESTIC SWINE, WITH SPECIAL REFERENCE TO TWO SPECIES PARASITIC IN THE STOMACH.

SUMMARY.

Two species of roundworms belonging to the family *Filariidae*, of particular interest to helminthologists and veterinarians on account of their wide distribution and frequency of occurrence in American swine and the possibility that they may cause serious injury to their host, are given special consideration in this paper.

One of these species, identified as *Spiroptera strongylina*, has recently been placed in a new genus, *Arduenna*, of which it is the type, and several errors regarding the anatomy of this parasite have been corrected. Another species, *Arduenna dentata*, has been found in China associated with *Arduenna strongylina*, and although not yet reported in American swine is mentioned in this connection, as further investigation may reveal its presence in this country.

Arduenna strongylina is much more common in American swine than it is said to be in European swine, and has been found abundantly in the slaughterhouses at St. Louis, Chicago, South Omaha, and Kansas City, and has also been collected at Benning, D. C., and Bethesda, Md.

Specimens of hogs' stomachs received from Chicago showed the worms deeply fastened in the submucosa or embedded in necrotic tissue near which were deep ulcers. The condition suggested infection with *Bacillus necrophorus*, the inoculation of which might easily result from the burrowing of the worms; however, owing to the sterile condition of the specimens received, this could not be satisfactorily demonstrated. A similar diseased condition of the stomachs of hogs in Europe is attributed by Von Rätz (1899d)¹ to infection with *Arduenna strongylina*. Under the circumstances the worm should be regarded with grave suspicion, and general prophylactic measures for the prevention of the spread of infection are suggested.

Commonly associated with *Arduenna strongylina* in this country is another worm, identified as *Physocephalus sexalatus*, first described by Molin (1860b) from specimens from the peccary (*Dicotyles labiatus*) from Brazil; also found by him associated with *Arduenna strongylina* from the wild boar in Germany. It is also reported by Von Linstow (1879b) (who apparently mistook this species for *Arduenna strongylina*) and Piana (1897e), from Europe, and by Railliet and Henry (1911b), from Madagascar and Indo-China, in the former case associated with a severe gastritis. Seurat (1912) has recently reported this species from the ass and dromedary in Algeria, but his statements would seem to require confirmation.

According to the writer's experience, *Physocephalus sexalatus* is almost as widely distributed as *Arduenna strongylina*, since out of eight lots of specimens of the latter species, specimens of *Physocephalus sexalatus* were found in all but one. In a mixed infection, however, it has never been found as abundantly as *Arduenna strongylina*. This worm has apparently the same habit of injuring the mucosa as has *Arduenna strongylina*, as both species were found in the same necrotic tissue in a hog's stomach. It must therefore be considered only less dangerous because it is less abundant, and should be subject to the same treatment suggested for infestation with *Arduenna strongylina*.

¹ References to literature will be found in bibliography at end of bulletin.

Nothing is known in regard to the life cycle of these parasites, but their wide distribution and frequency of occurrence suggest a simple life history without an intermediate host. The fact that the eggshells of both species are relatively thick would seem to indicate that the embryos are not liberated until the shell is dissolved by the gastric juice of the host. From the fact that the embryos are fairly well developed before oviposition, it may be inferred that the eggs require but a short period of incubation.

Following the discussion of the two species is a key for use in the identification of roundworms parasitic in swine; also a list of these parasites classified according to their zoological position.

INTRODUCTION.

Nematodes occurring in the stomach are commonly present among swine in the United States. These have usually been considered by veterinarians, pathologists, and others who have had occasion to mention them as belonging to the species *Spiroptera strongylina* Rudolphi, 1819, although some have expressed a doubt as to the correctness of the identification. In addition to the forms which have been identified as *Spiroptera strongylina*, Hassall and Stiles (1892a) have described a species named by them *Strongylus rubidus*, and which has since been collected from domestic swine in Europe.

Recently a zoological study of specimens of nematodes in the helminthological collection of the Bureau of Animal Industry, collected from the stomachs of hogs in various parts of the United States, was undertaken by the present writer, largely as a result of reports from inspectors relative to the prevalence of nematodes in the stomachs of swine, Drs. J. J. Brougham and T. B. Pote, of the St. Louis station, having been among the first in the Federal service to give attention to the subject from the standpoint of meat inspection. As a result of this study and of a comparison of these specimens with specimens of *Spiroptera strongylina* received from Europe, the conclusion has been reached that in several particulars the descriptions of *Spiroptera strongylina* commonly given by European writers are in error, and that the forms commonly identified as *Spiroptera strongylina* represent two distinct species, one of them *Spiroptera strongylina*, the other corresponding to *Physocephalus sexalatus* (Molin, 1860) Diesing, 1861, hitherto considered a rare parasite and until recently reported only once for domestic swine.

According to Stiles and Hassall (1905b), the genus *Spiroptera* is preempted by the genus *Acuaria* Bremser, 1811, whose type is *anthuris*. This species is also the type of *Dispharagus* Dujardin, 1845, a genus based largely on certain nematodes of birds and not found in mammals. According to this ruling, the genus *Acuaria* is confined to certain parasites of birds and fishes characterized by a differentiation in the structure of the esophagus. As *Spiroptera strongylina* does not conform to the type of *Acuaria* or the characteristics of the genus, a new genus to include these forms is necessary. This deficiency has

been supplied by the creation of a new genus, *Arduenna*, by Railliet and Henry (1911), *Spiroptera strongylina* being taken as the type. Both *Arduenna* and *Phyocephalus*, together with *Simondsia paradoxa*, belong in the family *Filariidæ*,¹ and are included by Railliet and Henry (1911b) in the new subfamily *Arduenninæ*.

FAMILY FILARIIDÆ, CLAUS, 1885.

FAMILY DIAGNOSIS.—Nematoda: Body long, filiform. Mouth surrounded with papillæ, or provided with two lips. Esophagus slender, without posterior bulb. Males with a single spicule or with two unequal spicules. Females with two ovaries; vulva usually in front of the middle of the body. Usually ovoviparous. Development in many cases requires an intermediate host.

TYPE GENUS.—*Filaria* Müller, 1787.

Subfamily ARDUENNINÆ Railliet and Henry, 1911.

SUBFAMILY DIAGNOSIS.—Filariidæ: Mouth with two lateral lips leading into a pharynx marked with cuticular ridges in the form of spirals or rings. Spicules unequal, the longer several times the length of the shorter. Four pairs of preanal papillæ. Eggs containing embryos when oviposited.

TYPE GENUS.—*Arduenna* Railliet and Henry, 1911.

Genus ARDUENNA Railliet and Henry, 1911.

GENERIC DIAGNOSIS.—Filariidæ: Body subcylindrical, attenuated anteriorly, posteriorly somewhat broader, usually curved in a semicircle, marked by a narrow, longitudinal cuticular wing on the left side, extending nearly the length of the body. Cuticle densely striated transversely. Mouth with two lateral lips, each lip with three lobes, leading into a small buccal capsule containing two lateral teeth, and followed by a cylindrical pharynx marked with cuticular ridges forming a series of spirals. Esophagus continuous, gradually broadening posteriorly and occupying from one-fourth to one-third of the body length. Caudal end of the male curved in a single turn. Bursa asymmetrical, the right bursal wing being broader than the left wing, furnished with five pairs of stalked papillæ asymmetrically arranged, of which one pair is preanal, three pairs are adanal, and the fourth pair is postanal. Bursal membrane marked with longitudinal and transverse striae, giving it a wrinkled appearance. Anus surrounded by a cuticular thickening, serrated on the outside edge. Spicules long and very unequal, the longer five to seven times the length of the shorter. Vulva anterior of the middle of the body. Eggs with thick shells containing embryos at the moment of oviposition. Parasitic in the stomachs of Suidæ.

TYPE SPECIES: *Arduenna strongylina* (Rudolphi, 1819), Railliet and Henry, 1911.

¹ Diesing (1861a) proposed the family name *Spiruridea* for a group of nematodes distinguished from *Filaria* by the curl or spiral twist of the tail of the male. This family is not accepted by most recent writers on the ground that it is not based on sufficiently characteristic morphological features, and that the name does not conform to the rules of zoological nomenclature. Oerley (1885a), Leiper (1908), and Railliet and Henry (1911b) use the name *Spiruridae*, apparently modifying Diesing's (1861a) family name *Spiruridea* to conform to the present zoological nomenclature. The family name *Spiropteridæ* is proposed by Leiper (1911).

Owing, however, to the apparent invalidity of the name *Spiroptera*, the present writer prefers not to use either the family name *Spiruridae* or *Spiropteridæ*, and although it is evident that the genera *Arduenna* and *Phyocephalus*, and other genera as well, will ultimately be separated from the *Filariidæ*, it is not considered desirable to attempt such a revision until a more careful study has been made of the various species involved. In the present paper, therefore, *Arduenna* and *Phyocephalus* are retained in the family *Filariidæ* but included under the subfamily *Arduenninæ*, Railliet and Henry, 1911.

Arduenna strongylina (Rudolphi, 1819) Railliet and Henry, 1911.

1819: *Spiroptera strongylina* Rudolphi, 1819a, p. 23.
 1819: *Spiroptera strongylina* Rudolphi, 1819a, p. 237. Misprint for *Spiroptera*.
 1828: *Spiroptera strongyliformis* De Blainville, 1828a, p. 546.
 1866: *Filaria strongylina* (Rudolphi) Schneider, 1866a, p. 101.

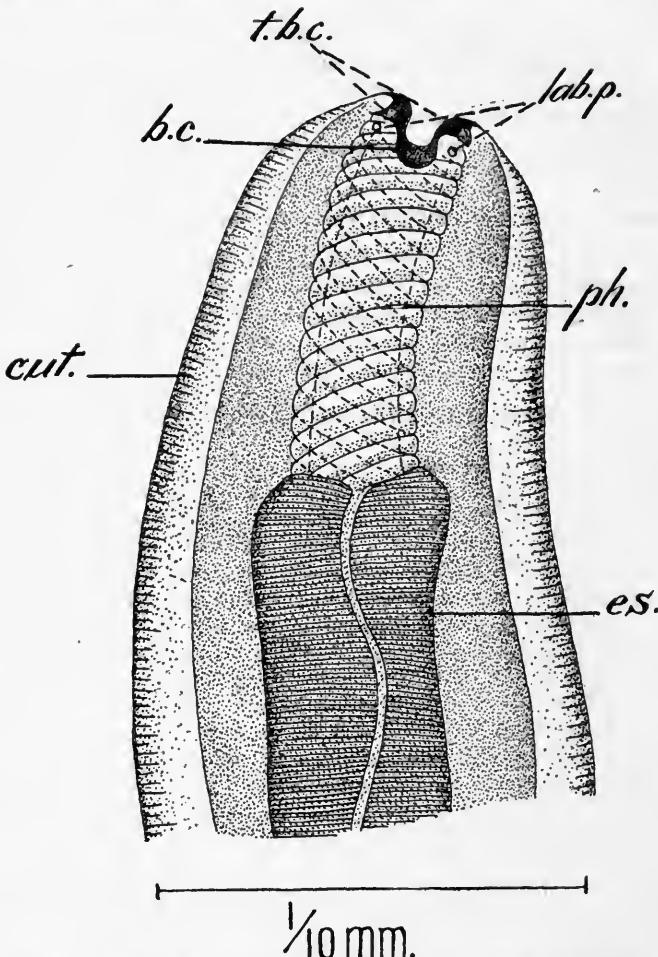


FIG. 1.—*Arduenna strongylina*. Median view of cephalic end. *b. c.*, buccal capsule; *cut.*, cuticle; *es.*, esophagus; *lab. p.*, labial papillæ; *ph.*, pharynx; *t. b. c.*, teeth of the buccal capsule. $\times 560$. (Original.)

SPECIFIC DIAGNOSIS.—Cuticle densely striated transversely, increasing in thickness toward the anterior extremity, which is furnished with two cervical papillæ placed asymmetrically, the left being about $190\ \mu$ and the right $390\ \mu$ from the anterior extremity. Beginning at a point $280\ \mu$ from the anterior end on the left side, a narrow cuticular wing gradually increasing to a maximum breadth of $35\ \mu$ extends to a point about $2\ mm.$ from the posterior extremity. Mouth 44 to $45\ \mu$ in diameter with two lateral lips each with three lobes, having a small round papilla at the base of each of the lobes. Just below the lips and projecting into the mouth cavity are two chitinous teeth, formed by a prolongation of the wall of the pharynx (fig. 1). The pharynx, $29\ \mu$

wide by 83 to 98 μ long, is marked on the inside by a series of chitinous ridges in the form of continuous spirals (or a multiple spiral), all running in the same direction and appearing like the threads of a quadruple screw.

Esophagus 3.1 to 3.7 mm. long, or about one-fourth of the body length, and 117 to 127 μ wide at its widest part near the base. Nerve ring 0.35 mm. and excretory pore 0.48 mm. from the anterior end.

Male 10 to 15 mm. long, averages about 13 mm. in length; 301 to 387 μ wide at the widest part just above the bursa. The bursal wings extend from a point about 1.2 mm. from the caudal extremity to the tip, the body ending in a blunt point. Bursal wings irregularly ovate, asymmetrical, the right bursal wing being about twice as wide as the left wing. The bursa contains 5 pairs of stalked papillæ asymmetrically arranged, of which 4 pairs are preanal and the last pair is post-anal. Bursa marked with fine longitudinal striae, increasing in density toward its base (fig. 2). Spicules two, grooved on the ventral surface, the left spicule 2.24 to 2.95 mm. long, very slender, ending in a fine point and presenting a slightly concave surface near the tip on the dorsal side. The right spicule (about one-fifth of the length of the left spicule) is stouter and blunter at the point, measuring 10 μ at its base, or nearly twice the width of the base of the long spicule, and is 457 to 619 μ long (fig. 3). Anus 155 to 200 μ from the posterior end and surrounded on the posterior and left side by a cuticular thickening (circumanal ring), the outer edge of which is serrated.

Female 16 to 22 mm. long, 263 to 420 μ wide; average maximum width 368 μ , at a point about one-third of the distance from the head to the caudal end. For the next third of the distance the width remains constant except for a slight constriction in the region of the vulva. Beginning at a point about two-thirds of the distance from the head to the caudal end, where one of the uteri turns back on itself, the width gradually diminishes and then abruptly decreases a short distance in front of the anus. Anus 215 to 275 μ from the caudal tip (fig. 4).

The orbicular naked vulva opening near the left side close to the lateral cuticular wing is slightly anterior of the middle of the body, dividing the worm anteriorly and posteriorly in the ratio 5:6. Vagina uniform, about 49 μ in diameter, 1.7 mm. long,

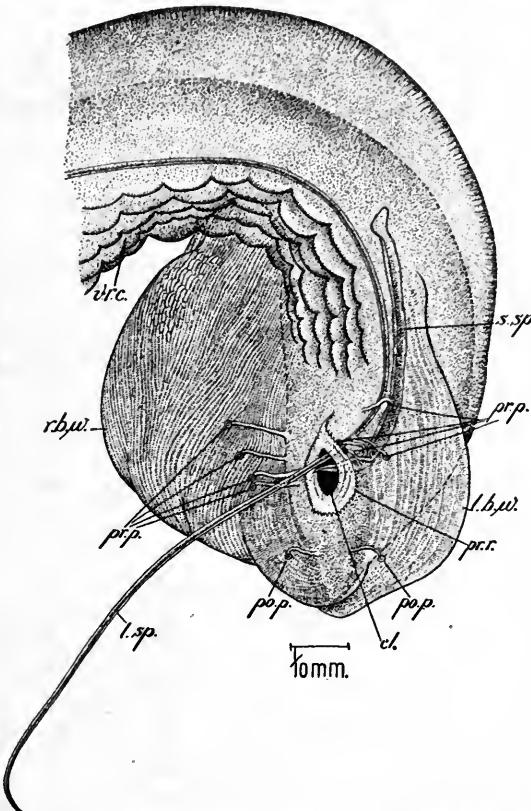


FIG. 2.—*Arduenna strongylina*. Bursa of male, ventral view. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, post-anal papillæ; *pr. p.*, preanal papillæ; *r. b. w.*, right bursal wing; *s. sp.*, short spicule; *v. r. c.*, ventral ridge of the cuticle. $\times 75$. (Original.)

extending in a generally posterior direction, joining the uteri at a point about 1.1 mm. from the vulva measured in a straight line (fig. 5).

Eggs oval, 34 to 39 μ long by 20 μ wide, with thick shells. Embryos well developed in the shell before oviposition (fig. 6).

HOSTS.—Domestic hog (*Sus scrofa domestica*), wild boar (*Sus scrofa sfera*).

LOCATION.—Stomach and small intestine.

LOCALITIES COLLECTED.—United States: Bethesda, Md.; Benning, D. C.; Chicago, Ill.; South Omaha, Nebr.; St. Louis, Mo.; Kansas City, Mo.; Denver, Colo.; Brazos

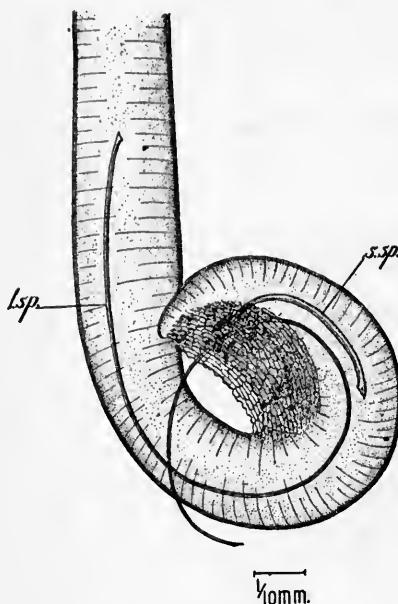


FIG. 3.—*Arduenna strongylina*. Posterior end of body of male, viewed from right side. *l. sp.*, long spicule; *s. sp.*, short spicule. $\times 65$. (Original.)

County, Tex. Europe: Germany, France, Hungary, Roumania, Italy. Asia: Turkestan, Indo-China.

The number of spiral ridges in the pharynx seems to vary both with the sex and among different individuals of the same sex. In the specimen figured, a female (fig. 1), there are four separate ridges, the usual number for females. Males have, as a rule, but three spirals. Railliet and Henry (1911b) mention 2 to 3 spiral ridges for males and 4 to 5 for females.

The retractor muscles controlling the movements of the right spicule are a pair of narrow lamellar strips, longitudinally finely striated, asymmetrically twisted in the center, attached at the posterior end to the spicule and at the anterior end to the ventral side

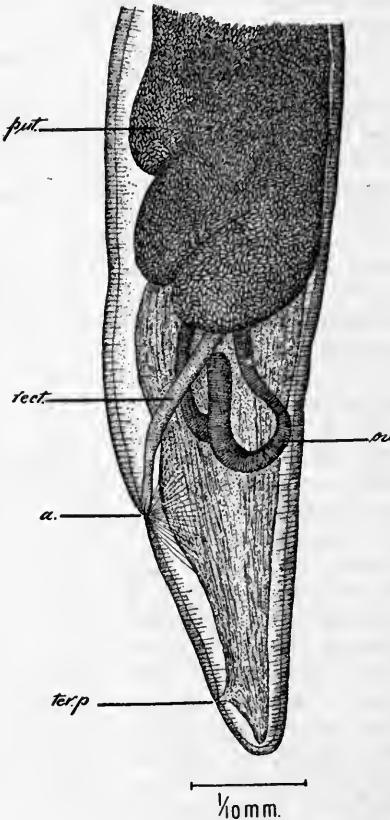


FIG. 4.—*Arduenna strongylina*. Posterior end of body of female, viewed from left side. *a.*, anus; *ov.*, ovary; *p. ut.*, posterior uterus; *rect.*, rectum; *ter. p.*, terminal papilla. $\times 150$. (Original.)

of the body. The muscles are fully as long as the spicule they control (fig. 7).

The vas deferens appears as a tube of darker color than the intestine, about $130\ \mu$ in its average diameter, and extending throughout the posterior third of the body length. About $450\ \mu$ from its terminus it rapidly diminishes in diameter toward the cloaca, and in the specimen figured (fig. 8) is bent in the shape of the letter S. The seminal tube is very long and convoluted, resembling in appearance the ovaries of the female. Near the posterior end of the male the intestine, $123\ \mu$ wide, first crosses above the vas deferens toward the dorsum, then curves underneath as it approaches the cloaca. Its terminus was obscured by the organs lying above it. In the specimen figured (fig. 8) the sheath of the right spicule is much contracted and appears as a dark-colored bag too short to contain the entire spicule and within which the base of

the spicule may be dimly seen. The ventral surface of the male in the region immediately anterior of the bursa is fur-

nished with 7 to 8 parallel longitudinal cuticular ridges divided transversely into serrations. This structure, modifications of which are seen in many nematodes, including *Physocephalus sexalatus*, probably assists in maintaining the position of the male in copulation, as suggested by Ciurea (1911). The anus is partially encircled by a rim of thickened cuticle, the outer edge of which is ornamented with serrated cuticular projections. This cuticular thickening extends along the posterior and left sides of the anus, forming about

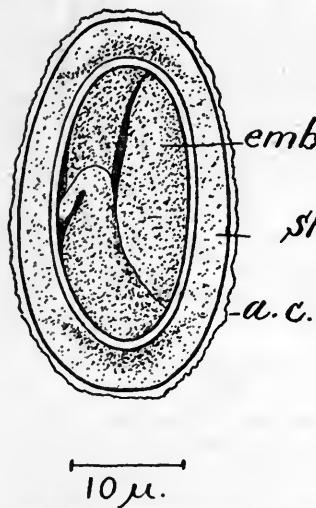


FIG. 6.—*Arduenna strongylina*. Lateral view of egg removed from a ruptured uterus. *a. c.*, albuminous covering; *emb.*, embryo; *sh.*, shell. $\times 1,450$. (Original.)

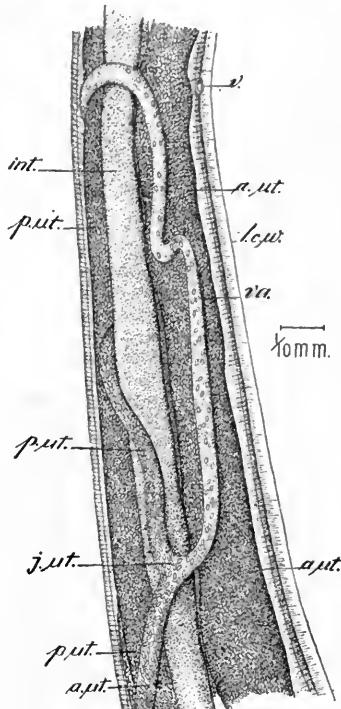


FIG. 5.—*Arduenna strongylina*. Ventral view of middle of body of female. *a. ut.*, anterior uterus; *int.*, intestine; *j. ut.*, junction of the uterus; *l. c. w.*, lateral cuticular wing; *p. ut.*, posterior uterus; *v. vulva*; *va.*, vagina. $\times 58$. (Original.)

two-thirds of a complete circle. The thickened cuticle seems to project downward into the body (fig. 2).

Ciurea (1911) depicts 10 tactile papillæ located on the ventral surface of the body of the male, close to the tip of the tail. These could not be seen in the specimens studied by the writer. The rectum (fig. 4) of the female is about $80\ \mu$ in maximum width and nearly as long as the distance from the anus to the tip of the tail. In the region immediately posterior of the anus several fine lines

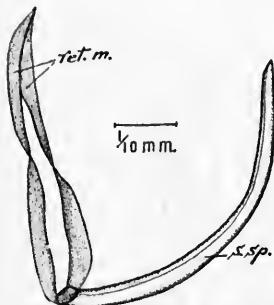


FIG. 7.—*Arduenna strongylina*. Short spicule with retractor muscles viewed from right side. *ret. m.*, retractor muscles; *s. sp.*, short spicule. $\times 80$. (Original.)

can be seen beneath the cuticle, converging toward the base of the anus. These are probably muscle fibers controlling the rectum, and are seen in the females of many nematodes. A pair of papillæ close to the tip of the tail extend laterally to the edges of the caudal cuticle on the ventral side.

In a cross section of *Arduenna strongylina* (fig. 9 of the present article), Ciurea (1911) shows that the interior of the lateral wing is filled with a substance shaped like the letter V when viewed in this position. In its reaction to hematoxylin it resembles the thickened wall of the pharynx.

The same drawing (fig. 9) also shows that the vagina first passes between the cuticle and muscular wall as it crosses the body to extend along the right side. In several of the specimens examined by him, Ciurea (1911) noticed a drop of hardened cement at the opening

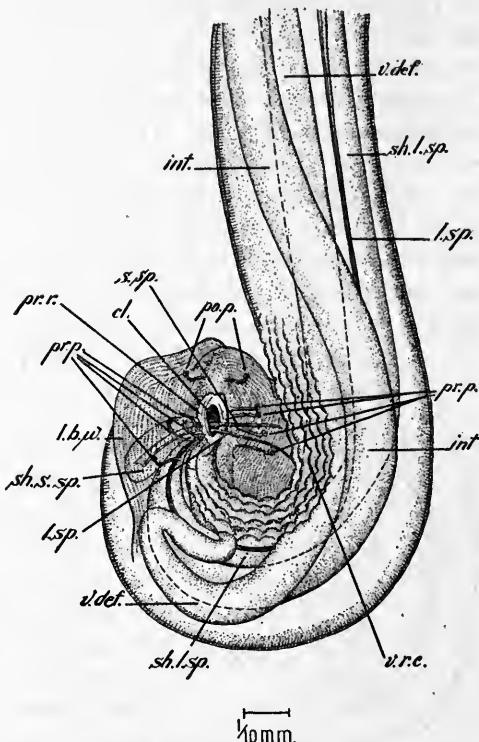


FIG. 8.—*Arduenna strongylina*. Posterior end of body of male, viewed from left side. *cl.*, cloaca; *int.*, intestine; *l. b. w.*, left bursal wing; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring; *sh. l. sp.*, sheath of long spicule; *sh. s. sp.*, sheath of short spicule; *s. sp.*, short spicule; *v. def.*, vas deferens; *v. r. c.*, ventral ridge of the cuticle, $\times 58$. (Original.)

of the vulva, and in cross section it was seen that the same material filled the terminus of the vagina. This material was not seen in any of the specimens examined by the present writer.¹

The vagina (fig. 5) extends first transversely under the uteri and intestine; then leading above these organs it continues posteriorly and parallel with the intestine (except for an S-shaped bend near its middle) along the right side until it reaches the junction of the uteri.

One of the uteri, commencing at the end of the vagina, extends posteriorly and dorsally without convolutions (except for an S-shaped bend 875 μ from its vaginal end) until it reaches a point 3.6 mm. from its union with

the vagina. Here it makes an abrupt turn, runs back anteriorly and ventrally, parallel-

with its dorsal limb, until its outline is lost to view beneath the mass of eggs distending both uteri and filling the body cavity from the end of the esophagus to within a short distance of the anus, greatly obscuring the outlines of the organs. Throughout its visible length this uterus is of nearly uniform diameter, about 95 μ . The distal ends of the two uteri are at opposite extremities of the worm; the uterus that first extends posteriorly ends anteriorly at a point 613 μ anterior of the base of the esophagus in a long convoluted ovary crowded into the narrow space between the esophagus and the lateral muscular wall. The other uterus, running in a similar but reverse direction from the uterus

FIG. 10.—*Arduenna strongylina*. General view of body of male from right side. *b.*, bursa. $\times 7$. (Original.)

just described, turns first anteriorly for about 3.5 mm., then posteriorly, ending at a point about 875 μ from the tip of the tail. The diameter of the posterior uterus, like that of the anterior uterus, is nearly

¹ Such a secretion is not, however, uncommon among nematodes. The writer has collected many specimens of *Oesophagostomum columbianum* the vulva of which was closed by a plug of dark-red secretion insoluble in alcohol but which could easily be removed by a needle. Specimens of this parasite have been observed so firmly welded in copulation that hot alcohol did not cause their separation and they yielded only to forcible traction with a needle or forceps.

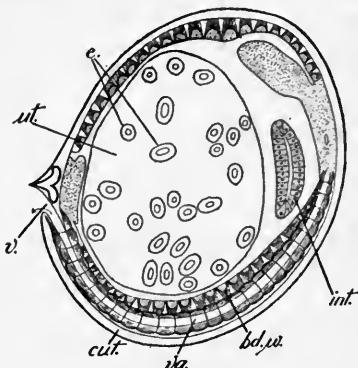
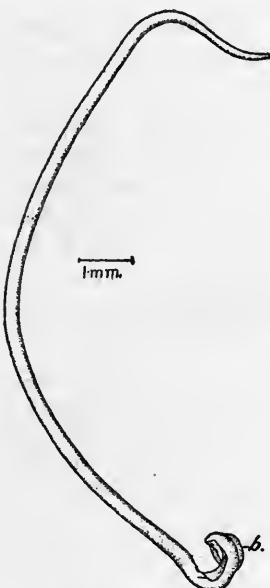


FIG. 9.—*Arduenna strongylina*. Cross section through body of female in the region of the vulva. *bd. w.*, body wall; *cut.*, cuticle; *e.*, eggs; *int.*, intestine; *ut.*, uterus; *v.*, vulva; *va.*, vagina. Enlarged. (After Ciurea, 1911. Text fig. 1, p. 131.)



uniform, about 95μ . The posterior ovary, much convoluted, fills most of the space between the anus and the terminus of the posterior uterus (fig. 4). The ovaries are long filiform tubes, 34μ in diameter in their narrowest part. The thick-shelled eggs are covered with a thin irregular membrane resembling the albuminous membrane of an ascarid egg. Under high power a faint line at either pole can be seen running transversely through the thickness of the shell, suggesting an operculum. The embryo is surrounded by a thin envelope, differentiated from the shell by its greater translucence and lack of granulation (fig. 6). Most of the eggs in the uterus contain well-developed embryos, but a few near the ovaries appear in the morula stage. The shell, including the translucent membrane surrounding the embryo, is 4μ thick, the embryo occupying a space 11μ by 24μ .

The general appearance of the two sexes is represented in figures 10 and 11.

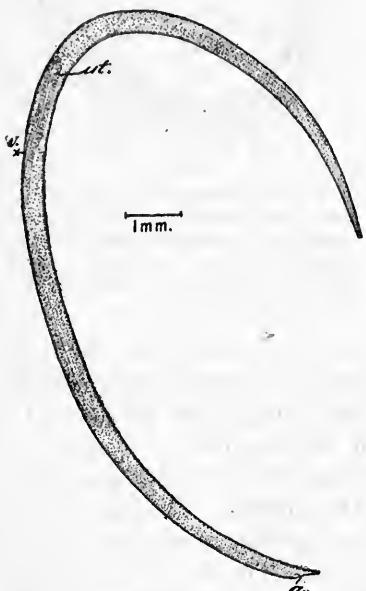
The first specimens of *Arduenna strongylina* were collected by Bremser and figured by him in his *Icones Helminthum* (Bremser 1824c). They were first described, however, by Rudolphi (1819a, p. 237). His description may be freely translated as follows:

Head slender, continuous, mouth orbicular, body somewhat attenuated anteriorly, tail of male coiled either in a single spiral or in a spiral and a half. A broad wing extending on either side of the tail. Spicule very long. Apex of the tail very short, naked. Apex of the tail of the female depressed, straight, subacute.

FIG. 11.—*Arduenna strongylina*. General view of body of female from left side. *a.*, anus; *ut.*, uterus; *v.*, location of vulva. $\times 7.5$. (Original.)

In a preliminary note Rudolphi (1819a) gives the measurement of the males as about 5 lines long ($= 10.6$ mm.) and the females as 7 lines long ($= 14.9$ mm.).

Gurlt (1831a) is the first on record to collect the worm from domestic swine. His description of the anatomy of *Spiroptera strongylina* follows Rudolphi's, but contains also the statement that the vulva is situated a short distance in front of the anus. He describes the mouth as smooth, without papillæ. Subsequently (Gurlt, 1847a) he added to his description a note on the anatomy of the pharynx, the first reference to this structure, which he describes as banded by two spiral muscles (a misinterpretation of the spiral chitinous ridges of



the pharynx) running the length of the esophagus in opposite directions (fig. 12).

Molin (1860b) describes the vulva as situated posteriorly, and gives the following measurements: Males, 11 to 15 mm; females, 15 to 23 mm, which figures agree closely with the writer's measurements of *Arduenna strongylina*.

Schneider (1866a) reexamining Rudolphi's material, gives a correct drawing of the bursa of *Arduenna strongylina*, showing 5 pairs of papillæ, of which one pair is postanal, and describes the anus as surrounded posteriorly by a crown of serrated cuticular prominences (fig. 13). His description, however, does not in all respects agree with his drawing, as he states that there are 6 pairs of papillæ while the drawing shows only 5 pairs. His description is also in error in regard to the position of the vulva, which he describes as directly in front of the anus.

Von Linstow (1879b) states that the two spicules measure respectively 0.72 and 0.26 mm. and that the mouth is surrounded with 6 round papillæ curved forward (fig. 14). His drawing shows the pharynx with a series of parallel ridges instead of a spiral. A comparison of his drawing (fig. 14) with the anterior end of *Phyocephalus sexalatus* (fig. 15) gives rise to the suspicion that Von Linstow has mistaken this species for *Arduenna strongylina*, an opinion first expressed by Railliet and Henry (1911b).

Zuern (1882a) is the first to mention the narrow lateral wing, extending longitudinally along one side of the body. He describes it, however, as being in a median position. As has been shown, it extends along the left side only.

Stossich (1897b) states that the long spicule is three times the length of the short spicule, a ratio evidently derived from Von Linstow's (1879b) measurements.

FIG. 13.—*Arduenna strongylina*. Bursa of male, ventral view. *cl.*, cloaca; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring. Enlarged. (After Schneider, 1866a, p. 101.)

At a meeting of the Helminthological Society of Washington, the writer (Foster, 1911) presented a note on *Spiroptera strongylina* in which he pointed out the differences between the anatomical features of specimens tentatively identified by him as *Spiroptera strongylina*

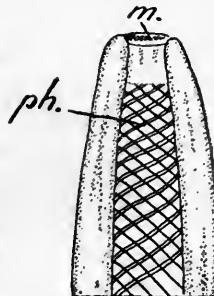
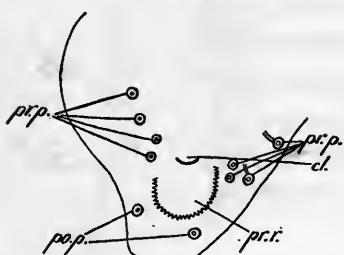


FIG. 12.—*Arduenna strongylina*. Cephalic end, *m.*, mouth; *ph.*, pharynx. Enlarged. (After Gurlt, 1847a, Pl. I, fig. 8.)



and the descriptions of this species by European observers. As no European specimens were at hand with which to compare the specimens collected in this country, it was concluded either that the

American form represented a distinct species or else the descriptions of European writers were in error in some important details. In order to determine which of the two alternatives was correct, specimens collected in the United States were forwarded to Prof. von Linstow for comparison with specimens collected in Europe, and other European helminthologists were asked for specimens of *Spiroptera strongylina*.

FIG. 14.—*Phyocephalus sexalatus*. Lateral view of cephalic end. *lab. p.*, labial papillæ; *ph.*, pharynx. Enlarged. (After Von Linstow, 1879b, Pl. V, fig. 11.)

teria strongylina. The specimens sent to Von Linstow were considered by him to be a different species from *Spiroptera strongylina*. There is, however, no question that certain European specimens recently received from Prof. Gedoelst, of Brussels, are specifically identical with the American form, nor can it be doubted that the form taken by Railliet and Henry (1911b) as *Spiroptera strongylina* is the same as the American form.

In regard to the length of the spicules of *Arduenna strongylina*, the writer's observations are not in accord with those of Ciurea (1911). Measurements of the spicules of over 35 males made with the aid of a camera lucida and stage micrometer show that the long spicule varies between 2.24 and 2.95 mm. in length, while the short spicule is between 457 and 619 μ in length. The corresponding measurements given by Ciurea are, long spicule, 977 μ ; short spicule, 221 μ . The measurements given by Railliet and Henry (1911b) are, long

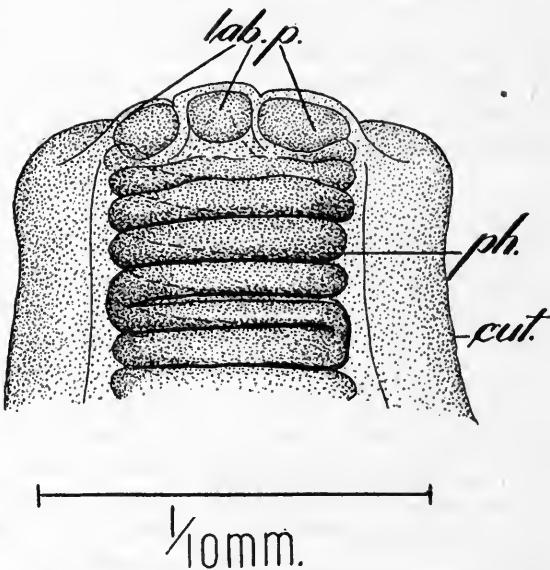
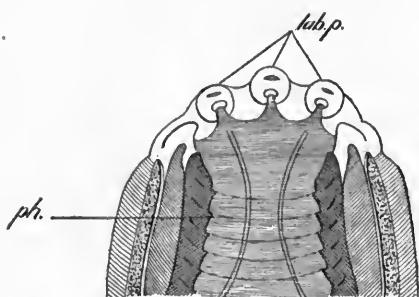


FIG. 15.—*Phyocephalus sexalatus*. Lateral view of cephalic end. *cut.*, cuticle; *lab. p.*, labial papillæ; *ph.*, pharynx. $\times 415$. (Original.)

spicule, 2.75 to 2.9 mm.; short spicule, 500 to 570 μ , thus confirming the present writer's observations.

Arduenna strongylina, considered a rare parasite by Dujardin (1845a), Neumann (1892a), and Railliet (1893a), is now known to have a wide range. In this country at least it is very common, as will be shown later. In Europe it has been collected from the wild boar by Bremser (Rudolphi, 1819a) in Germany, and is reported by Dujardin (1845a) in Austria, and by Railliet and Henry (1911b) in France from the same host. It has been reported for domestic swine in Germany (Gurlt, 1831a), Hungary (Von Rätz, 1899d), Italy (Piana, 1897e), and Roumania (Ciurea, 1911). Most helminthologists, following the older writers, state that the parasite is rare and occurs somewhat more commonly in the wild boar than in domestic swine. Dujardin (1845a) states that "out of 19 wild boars dissected at the museum of Vienna, only 2 had this worm in the stomach." In Roumania, Ciurea found it in 9 out of 72 healthy swine, between 1 and 27 specimens being found in a single host. Outside of Europe it has been reported by Von Linstow (1886c) from Turkestan, and by Railliet and Henry (1911b) from Annam Province, Indo-China. Some doubt, however, may be expressed regarding the identity of the parasite reported by Von Linstow (1886c) since, as has been shown, Von Linstow (1879b) has apparently confused *Phyocephalus sexalatus* with *Arduenna strongylina*. The references to this parasite in the United States will be considered in detail in another part of the paper. Judging from its abundance in the United States, it seems not improbable that a careful examination of hogs' stomachs in European slaughterhouses would show a more widespread infection than hitherto reported. The specimens received by this bureau from Gedoelst were unaccompanied with any data giving the host or locality. Doubtless many veterinary schools and colleges throughout Europe contain specimens both of this parasite and of *Phyocephalus sexalatus* which, like the specimens received from Gedoelst, have never been reported in the literature.

An examination of the literature reveals only two authentic hosts for *Arduenna strongylina*, namely, the European wild boar and domestic swine, although most writers subsequent to Diesing (1851a) have included the peccary in their lists of hosts.

Deaths (1851a) identified as *Spiroptera strongylina* some specimens of worms in the Vienna museum collected by Natterer in Brazil, April 24, 1826, from the stomach of the white-lipped peccary (*Dicotyles labiatus*) and labeled *Spiroptera suis labiati*. As a result of his identification he (Deaths, 1851a) added *Dicotyles albirostris* (= *Dicotyles labiatus* Cuv.)¹ to the previously known hosts of *Spiroptera*.

¹ Dr. H. W. Henshaw, Chief of the Bureau of Biological Survey of the United States Department of Agriculture, in reply to a letter regarding the synonymy of *Dicotyles labiatus*, states (Feb. 24, 1911) that, according to Dr. J. A. Allen, of his bureau, *Dicotyles labiatus* and *albirostris* are synonyms, *labiatus* having preference as being the older term, the correct name, however, being *Tayassu pecari* Fischer.

strongylina. The specimens were subsequently studied by Molin (1860b), recognized as a new species, and named by him *Spiroptera sexalata*. Later helminthologists, although accepting Molin's species, have continued to include *Dicotyles labiatus* among the hosts reported for *Arduenna strongylina*, apparently ignoring the fact that Molin's (1860b) correction of Diesing's (1851a) identification eliminates the peccary as a host of *Arduenna strongylina*, since this species has never been reported in the peccary except by Diesing (1851a). Stossich (1897b) apparently considered *Dicotyles albirostris* and *D. labiatus* as separate species, listing under the former *Spiroptera strongylina* and under the latter the parasites collected by Natterer from the peccary and described by Molin (1860b).

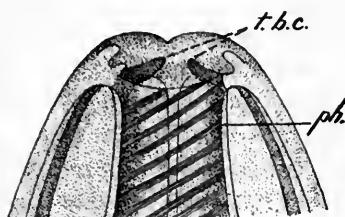


FIG. 16.—*Arduenna dentata*. Median view of cephalic end. *ph.*, pharynx; *t. b. c.*, teeth of the buccal capsule. Enlarged. (After Von Linstow, 1904f, Pl. I, fig. 5.)

normal location for *Arduenna strongylina*; Von Rätz (1899d), however, reports its occurrence in the small intestine.

Arduenna dentata (Von Linstow, 1904) Railliet and Henry, 1911.

Von Linstow's (1904f) description of this species is as follows:

Cuticula finely annulated. The mouth leads into a pharynx 0.11 mm. long. Its entrance is armed with a dorsal and a ventral tooth; the mouth is a transverse slit, the border of which shows both anteriorly and posteriorly, three notches with papillæ (fig. 16).

The esophagus measures $\frac{1}{8.6}$ of the entire length and presents a spiral musculature. In a young worm 14.6 mm. long, the nerve ring surrounds the esophagus 2.64 mm. from the head end, and the excretory pore opens at a point situated 0.31 mm. behind it. The male (25 mm. long by 0.79 mm. broad) has a closely involuted tail which resembles that of *Spiroptera strongylina*. The spicules are respectively 0.35 and 0.92 mm. long, the shorter one bearing at its end a barb. Immediately anterior of

the anus on each side there are four preanal papillæ situated close together; behind it there is one papilla. All have long stalks. The anus is surrounded by a broad ring, notched externally; the bursa shows longitudinal rows of oval scales. (Fig. 17.) The female grows to a length of 55 mm. with a width of 1.10 mm. The short conical tail is curved over the back; the vulva is placed far behind the middle and divides the body in the ratio of 70 to 23. The eggs are small, thick shelled, and cylindrical, measuring 0.039 by 0.017 mm.

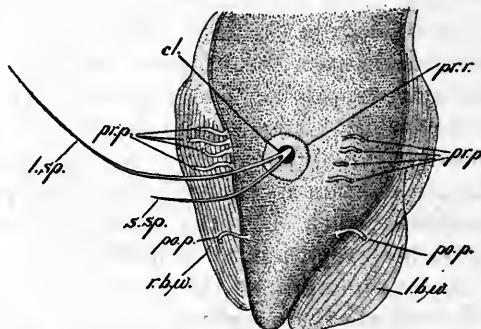


FIG. 17.—*Arduenna dentata*. Bursa of male, ventral view. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *pr. r.*, perianal ring. Enlarged. (After Von Linstow, 1904f, Pl. I, fig. 7.)

The specimens described by Von Linstow were from the stomach of *Sus cristatus* at Chilaw, Ceylon, and are deposited in the museum of Colombo. Railliet and Henry (1911b) identify with Von Linstow's (1904f) *Spiroptera dentata* certain parasites collected from the stomachs of pigs slaughtered at Hué, Annam Province, Indo-China, and include them in the genus *Arduenna*. The specimens examined by Railliet and Henry (1911b) differ, however, from Von Linstow's (1904f) description in the position of the vulva and the length of the spicules. According to the former authorities, the position of the vulva is difficult to observe, but the spicules measure 3.75 to 4.23 mm., and 540 to 650 μ , respectively.

The principal differences between *Arduenna dentata* and *Arduenna strongylina* are the greater size of the former and the fact that the chitinous ring surrounding the cloacal opening, described for *Arduenna strongylina*, forms an almost complete circle in the case of *Arduenna dentata*, while in *Arduenna strongylina* it includes only the posterior and left sides. Railliet and Henry's measurements for *Arduenna dentata* are: Males: 25 to 35 mm. long by 700 to 800 μ broad; females: 40 to 55 mm. long by 1.1 to 1.2 mm. broad.

Genus **PHYSOCEPHALUS** Diesing, 1861.

GENERIC DIAGNOSIS.—*Filaridiidae*: Body elongated, subcylindrical, slightly tapering anteriorly. Head marked off from the rest of the body by a cuticular inflation ending abruptly in a circular line a short distance anterior of the posterior end of the pharynx. Extending from the base of the cuticular inflation to about the middle of the body are 6 lateral cuticular wings, 3 on each side, the middle wing of each 3 being broader than the other two. Mouth with 2 trilobed lips, with a rounded papilla on each lobe, and leading into an inconspicuous buccal capsule without teeth. Pharynx relatively long and broad, marked by prominent ridges forming both spirals and simple rings, and extending the length of the pharynx on the inside. Tail of the male twisted spirally, furnished with a narrow symmetrical bursa supported by four pairs of preanal papillæ. Spicules long and unequal, the left spicule about five times the length of the right spicule. Vulva somewhat posterior of the middle of the body; eggs smooth, with thick shells, containing well-developed embryos at the moment of oviposition. Endoparasitic in the stomach of suidæ.

TYPE SPECIES.—*Physocephalus sexalatus* (Molin, 1860) Diesing, 1861.

Physocephalus sexalatus (Molin, 1860) Diesing, 1861.

1860: *Spiroptera sexalata* Molin, 1860b, p. 957.

1860: *Spiroptera strongylina suis labiati*: Molin, 1860b, p. 957
(Museum label).

1861: *Physocephalus sexalatus* (Molin) Diesing, 1861a, p. 686.

SPECIFIC DIAGNOSIS.—*Physocephalus*: Head about 60 μ in diameter at the anterior end, furnished with 2 trilobed lips, each lobe being ornamented with a thick, rounded chitinous papilla (fig. 15). The cuticle of the head, extending from the mouth to a point 232 μ from the anterior end, is more or less inflated. Pharynx cylindrical, 263

to 315μ long by 53μ wide, furnished with a spiral band which usually breaks up into separate rings in the middle of its course and resumes the spiral toward the posterior end. The number of turns to the spiral varies between 21 and 25. There is a cervical papilla on the left side, 281μ from the anterior end. The excretory pore opens on the right side, 526μ from the anterior end. The lateral cuticular wings, 3 on each side, commencing at the base of the cephalic cuticular inflation, extend posteriorly for a distance about one-third of the body length. The middle wing of each three is 60μ

wide at its middle, the point of greatest width. The other wings are about half as wide (fig. 18).

Male, 6 to 9 mm. long, measured in a straight line. Body nearly uniform in diameter, averaging 263μ , and attaining its greatest width of 315μ at the point of the greatest width of the lateral wings. The narrow bursal membranes, about half the width of the body, extend from a point about 1.4 or 1.5 mm. from the caudal extremity, to and including the bluntly pointed tip (fig. 19). Caudal extremity twisted into a fairly regular spiral, having usually three turns. Long spicule grooved on the ventral side, 2.1 to 2.25 mm. in length, or five to six times the length of the short spicule, very slender, gradually tapering to a fine needle point. Short spicule 300 to 350μ long, relatively broad at its base, suddenly tapering to a fine point. The ventral surface of the short spicule is provided with a narrow wing extending nearly to the tip. Bursa furnished with eight pairs of papillæ (fig. 20). Of these the four pairs of preanal papillæ are long and stalked; the postanal papillæ, close to the tip of the tail, are very small, with short stalks.

Female 13 to 19 mm. long,

average about 16 or 17 mm. Maximum width 333 to 450μ in the region directly anterior of the anus. The body rapidly increases in diameter from the anterior end to the region of greatest width of the lateral cuticular wings. At this point the diameter is nearly as great as in the region of the anus. It then rapidly diminishes to half as much at the end of the first third of the body; then slowly increasing, it reaches a maximum near the anus and abruptly diminishes, the body ending in a blunt point furnished with a mucronate tip. Anus 120μ from the caudal end, 50μ in diameter (fig. 21). Vulva posterior of the middle, 35μ in diameter, dividing the body in the ratio of 9 to 8. The vagina extends posteriorly (fig. 22). Uterus bilobed, the ovaries lying at opposite extremities. Eggs 34 by 15μ , slightly flattened at the poles. Embryo well developed before oviposition (fig. 23).

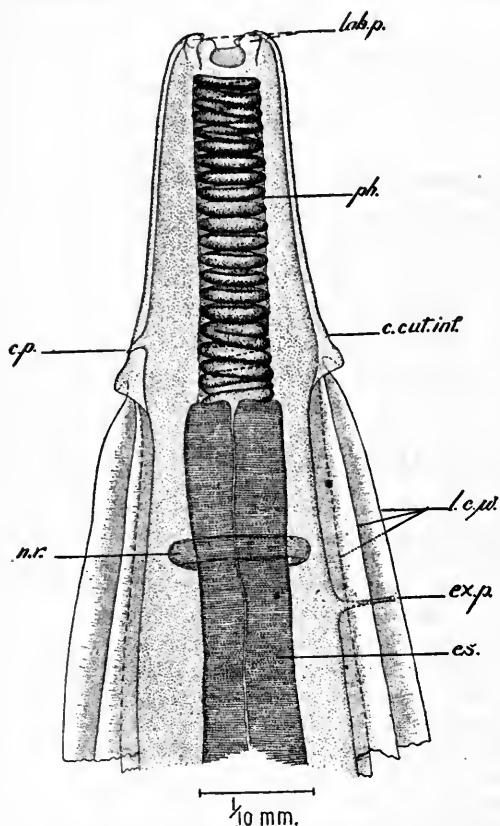


FIG. 18.—*Physocephalus sexalatus*. Dorsal view of anterior end of body. *c. cut. inf.*, cephalic cuticular inflation; *c. p.*, cervical papilla; *es.*, esophagus; *ex. p.*, excretory pore; *lab. p.*, labial papillæ; *l. c. w.*, lateral cuticular wings; *n. r.*, nerve ring; *ph.*, pharynx. $\times 150$. (Original.)

HOSTS.—White-lipped peccary (*Tayassu pecari*), wild boar (*Sus scrofa fera*), domestic hog (*Sus scrofa domestica*).

LOCATION.—Stomach and small intestine.

LOCALITIES COLLECTED.—Brazil; Italy; Germany; Roumania; Madagascar; Indo-China; United States, east, middle, and southwest. (Apparently same range as *Arduenna strongylina*.)

As already mentioned, *Phyocephalus sexalatus* was first identified as *Spiroptera strongylina* by Diesing (1851a). Molin (1860b) subsequently described the specimens under the name *Spiroptera sexalata*, and the following year Diesing (1861a) placed the species in a new genus *Phyocephalus*, of which it is the type and only species. The specimens studied both by Molin and Diesing were collected by Natterer from the white-lipped peccary in Brazil, April 24, 1826, and deposited in the Vienna Museum labeled *Spiroptera strongylina suis labiati*.

Molin's (1860b) somewhat meager description sums up the salient points (the lateral wings and spiral tail of the male) by which *Phyocephalus sexalatus* may be recognized. He describes the males as 7 mm. long and 2 mm. wide, and the females as 9 to 13 mm. long and 3 to 5 mm. wide. The mouth is described as bilobed, each lobe with a three-cornered margin. Diesing (1861a), although creating a new genus from Molin's species, adds little to our knowledge of its anatomy.

It has already been noted that Von Linstow (1879b) has apparently mistaken *Phyocephalus sexalatus* for *Arduenna strongylina*. His measurements of the spicules (0.72 mm. for the long and 0.26 mm. for the short spicule) are, however, much too short for *A. strongylina* and also for *P. sexalatus*.

Von Drasche (1884a), in his reexamination of Diesing's and Molin's specimens, made a careful study of the bursal papillæ and the struc-

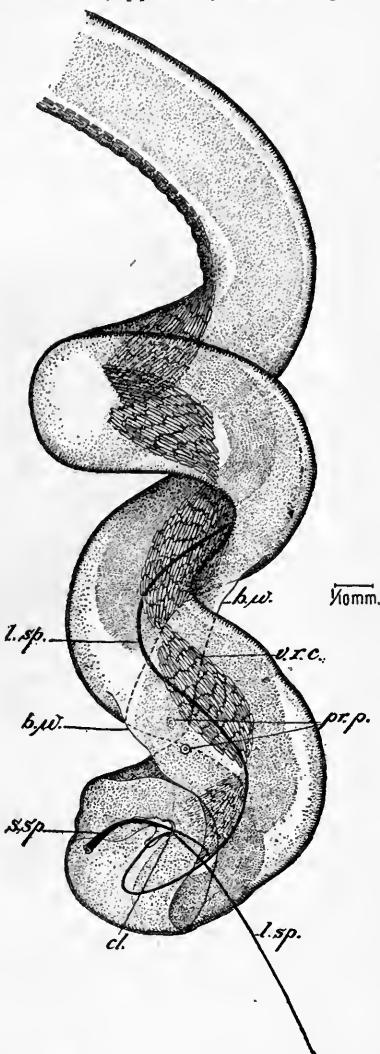


FIG. 19.—*Phyocephalus sexalatus*. Posterior end of body of male. *b. w.*, bursal wing; *cl.*, cloaca; *l. sp.*, long spicule; *pr. p.*, preanal papillæ; *s. sp.*, short spicule; *v. r. c.*, ventral ridge of the cuticle. $\times 50$. (Original.)

ture of the lateral wings, illustrating the description with drawings, which were of great value to the present writer in verifying his identification. In common with Railliet and Henry (1911b) the present writer was unable to find the pair of papillæ depicted by Von Drasche (1884a, fig. 24 of this article) close to the edge of the anus. Ciurea (1912), however, depicts a pair of papillæ immediately posterior of the anus, which he states are not easily seen. At the extreme tip of the tail Von Drasche (fig. 24) shows three pairs of minute apparently sessile papillæ. In reality there are four pairs of minute stalked papillæ at this point. These appeared very clearly with a high

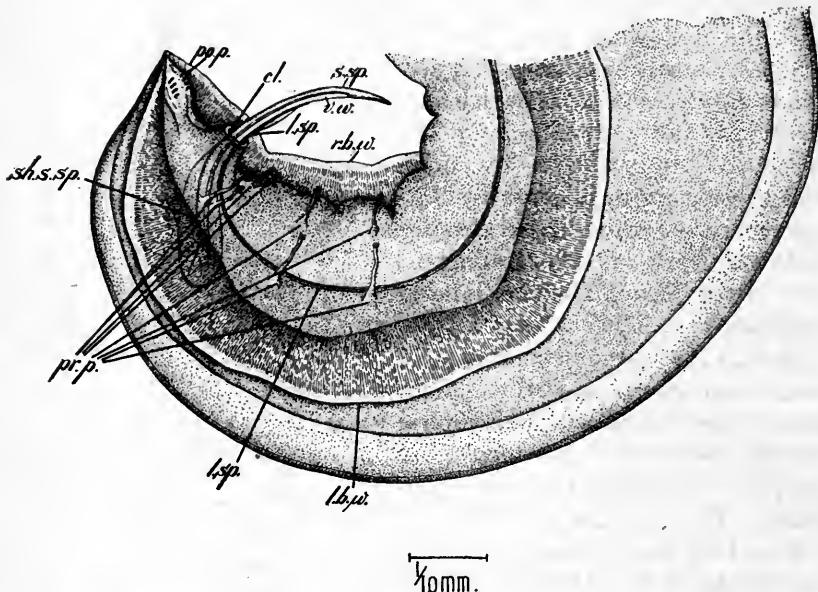


FIG. 20.—*Physocephalus sexalatus*. Bursa of male, viewed from left side. *cl.*, cloaca; *l. b. w.*, left bursal wing; *l. sp.*, long spicule; *po. p.*, postanal papillæ; *pr. p.*, preanal papillæ; *r. b. w.*, right bursal wing; *sh. s. sp.*, sheath of short spicule; *s. sp.*, short spicule; *v. w.*, ventral wing of short spicule. $\times 100$. (Original.)

power in mounts presenting a somewhat lateral view (fig. 20). The structure at the tip of the tail with its rows of minute papillæ is not unlike that depicted by Ciurea (1911) for the bursa of *Arduenna strongylina*. As already stated, however, no such structure was seen by the present writer on the bursa of this species. In a cross section of *P. sexalatus* (fig. 25) Von Drasche shows that the projecting cuticle forming the lateral wings has corresponding depressions inward.

Stossich's (1897b) description of *P. sexalatus* follows that of Molin and Von Drasche. Piana (1897e), in an article on *Simondsia paradoxra*, mentions finding two other species of nematodes in the same bottle containing the specimens of *Simondsia*. He identified these as being *Spiroptera strongylina* and *Physocephalus sexalatus*. These specimens were from an Italian pig.

Railliet and Henry's (1911b) description of *Phyocephalus sexalatus* is based on specimens collected from a hog slaughtered at Hué, Indo-China. These authors also report having observed it in material from Madagascar in 1905.

Ciurea (1912) reported *Spiroptera sexalata* in domestic swine slaughtered at Piatra Neamtz, Roumania, in 1910. Five out of 72 healthy swine were infested with from one to thirty of these para-

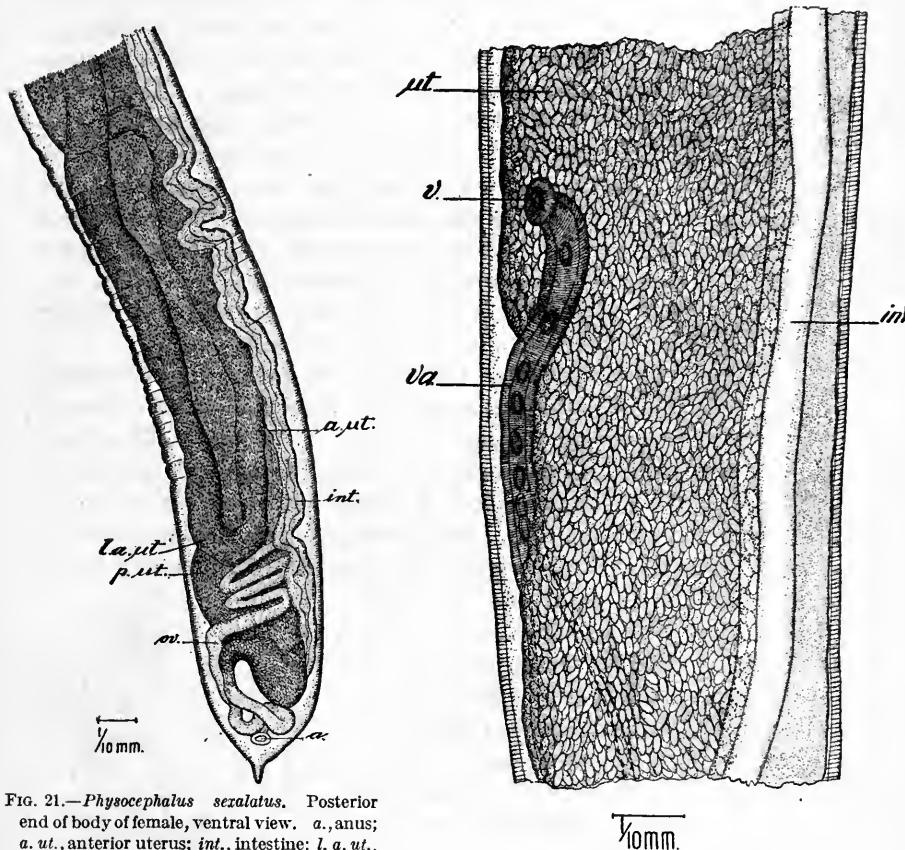


FIG. 21.—*Phyocephalus sexalatus*. Posterior end of body of female, ventral view. *a.*, anus; *a. ut.*, anterior uterus; *int.*, intestine; *l. a. ut.*, loop of anterior uterus; *ov.*, ovary; *p. ut.*, posterior uterus. $\times 50$. (Original.)

FIG. 22.—*Phyocephalus sexalatus*. Ventral view of body of female in the region of the vulva. *int.*, intestine; *ut.*, uterus; *v.*, vulva; *va.*, vagina. $\times 95$. (Original.)

sites in the stomach. In three cases they were found associated with *Arduenna strongylina*, and once with *Gnathostoma hispidum*. In this latter case the parasites were found in the ulcer caused by *G. hispidum*. The worms were partially or entirely buried in the mucosa, but no lesions were attributed to them. Ciurea's (1912) description and drawings of *Phyocephalus sexalatus* agree in most respects with the present writer's observations, the few differences being noted in the course of this article.

Seurat (1912) reports finding several hundred specimens of *Spipoptera sexalata* partially buried in the mucosa of the stomach of an ass slaughtered in Algeria during July, 1911.

A subsequent examination of the fourth stomachs of six dromedaries revealed numerous specimens of this species hidden between the folds of the mucosa, associated with *Haemonchus contortus*. While the description of the specimens agrees in general with the present writer's observations, the measurements are all somewhat larger. The width of the middle lateral wing (110 to 120 μ as given by Seurat) is over twice as great as that given by the present writer, while the vulva is described as located at the anterior third of the body, instead of slightly posterior of the middle, as described by Railliet and Henry (1911b), Ciurea (1912), and Foster (1912) (the present article).

Seurat (1912) also found in the dromedary another form which he considers as a variety and designates as var. *cristata*. This form is distinguished from the typical species by having four longitudinal crests on the head,

formed by four cuticular folds, and having four cuticular spines in the mouth cavity. In this variety the position of the vulva is not constant, but varies from the posterior third of the body to an anterior position.

As Seurat's (1912) measurements of *Physocephalus sexalatus* differ considerably from the present writer's, and as the species has hitherto been reported only in the Suidæ, it would seem desirable to reserve an opinion until his statements can be confirmed.

The stomach is the normal location for *Physocephalus sexalatus*. Von Linstow (1879b) reports *Filaria strongylina* as collected from the small intestine of a hog by Dr. V. Hering, of Stuttgart. As has been shown, Von Linstow apparently confused *Physocephalus sexalatus* with *Arduenna strongylina*; it would seem therefore, that *P. sexalatus* may occasionally occur in the small intestine.

In most specimens examined by the author the cuticle of the head appears as shown in fig. 18, which is closely similar to the form

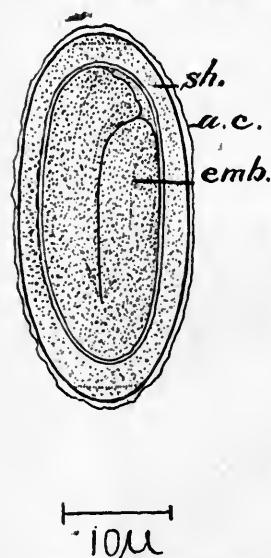


FIG. 23.—*Physocephalus sexalatus*. Lateral view of egg removed from a ruptured uterus. a. c., albuminous covering; emb., embryo; sh., shell. $\times 1,450$. (Original.)

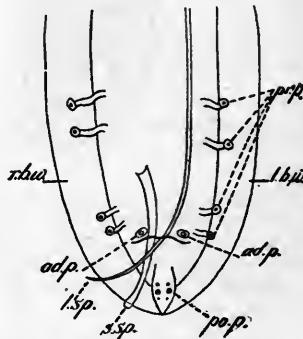


FIG. 24.—*Physocephalus sexalatus*. Bursa of male, ventral view. ad. p., adanal papillæ; l. b. w., left bursal wing; l. sp., long spicule; po. p., post-anal papillæ; r. b. w., right bursal wing; s. sp., short spicule. $\times 230$. (After Von Drasche, 1884a, Pl. XIV, fig. 3.)

depicted by Von Drasche (1884a). In about 20 per cent of the specimens examined, however, the cuticle, from the lips to the beginning of the lateral cuticular wings, is inflated into two hemispherical vesicular wings (fig. 26). This second form is not mentioned by Molin (1860b) or Von Drasche (1884a), but possibly may be referred to by Diesing (1861a) in the expression "epidermide in bullam inflata tunicatum" in his description of the genus *Phyocephalus*.

The pharynx of *P. sexalatus* is about three times as long and twice as broad as that of *Arduenna strongylina*, and this, together with the lateral wings characteristic of the genus, are the salient points in distinguishing the females of the two genera.

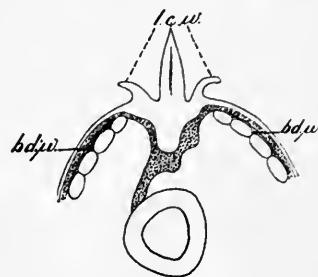


FIG. 25.—*Phyocephalus sexalatus*. Cross section through anterior part of body. *bd. w.*, body wall; *l. c. w.*, lateral cuticular wings. $\times 280$. (After Von Drasche, 1884a, Pl. XIV, fig. 4.)

At first sight the ridges of the pharynx appear to form separate rings and are so described by Von Linstow (1879b and *in litt.*). By careful focusing, however, it is seen that these ridges form a simple spiral at the anterior end of the pharynx and after making four or five turns split up into separate rings. At the posterior end of the pharynx they are again joined into a simple spiral (fig. 18). The final loop of the anterior spiral forms the first ring of the series, and the beginning of the posterior spiral takes its origin from the lower part of the last ring. The number of loops to the spirals and the number of separate rings is subject to considerable variation. A rather extreme case is seen in fig. 27. Here the first spiral has five loops followed by a detached ring. This in turn is followed by a spiral of four loops, after which are two detached rings. The final spiral consists of 11

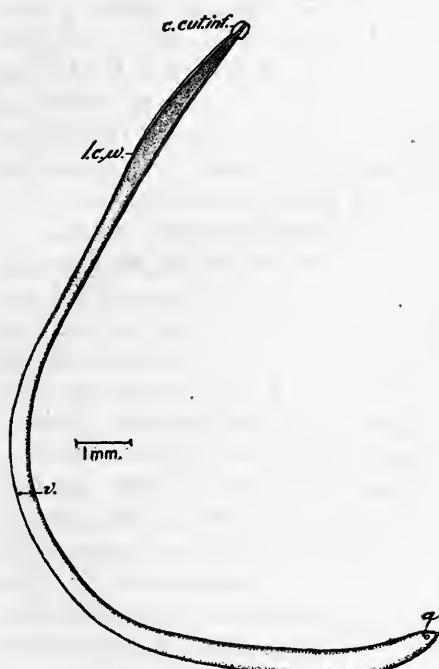


FIG. 26.—*Phyocephalus sexalatus*. Ventral view of body of female. *a.*, anus; *c. cut. inf.*, cervical cuticular inflation; *l. c. w.*, lateral cuticular wings; *v.*, vulva. $\times 7$. (Original.)

continuous loops. In every case, however, so far as observed, the ridges form both spirals and rings, commencing and ending with a spiral, and

not a series of parallel bands, as described by Von Linstow (1879b), or a continuous spiral, as described by Von Drasche (1884a), Railliet and Henry (1911b), and Ciurea (1912).

Railliet and Henry (1911b) mention two asymmetrical cervical papillæ, the right papilla being $220\ \mu$ and the left $420\ \mu$ from the anterior end.

As seen by the present writer the left papilla has a broad base and a blunt point and penetrates the cuticle $281\ \mu$ from the anterior end, or a little anterior of the base of the cephalic inflation. The right papilla was not seen by the present writer, but on the right side, not far from the location of the papilla as given by Railliet and Henry (1911b), the excretory canal opens. The end of the canal is a slender tube penetrating the middle lateral wing and looking not unlike a long stalked papilla (fig. 18). Its true nature has been shown by Ciurea (1912), who made a cross section of the worm at this point. The lateral situation of the excretory pore is apparently unique among nematodes, the usual situation being ventral.

The lateral cuticular wings unite just posterior of the base of the cephalic inflation (fig. 18). Here the cuticle forms an inverted pocket like the handle of a table drawer (fig. 27). The lateral cuticular wings are densely striated at the base, giving them a puckered appearance. Although the cuticle of the entire body is striated, these striations appear more prominently on the lateral wings, particularly at their base, than elsewhere.

The esophagus, about four-fifths of

the length of the lateral wings, is densely striated transversely, with a very narrow lumen; nerve ring $439\ \mu$ from the anterior end (fig. 18). The intestine is more or less convoluted throughout its course, especially posteriorly.

The male (fig. 28) is about half the length of the female, but as 2 to 3 mm. of the posterior end is twisted into a spiral, its apparent length is much shortened.

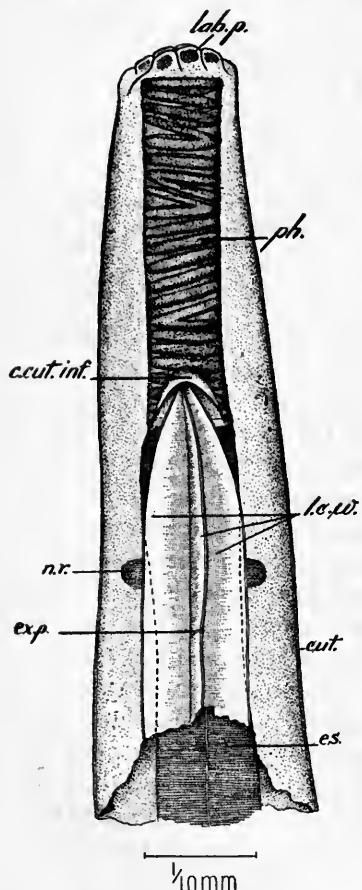


FIG. 27.—*Physocephalus sexalatus*. Lateral view of anterior end of body. *c. cut. inf.*, cervical cuticular inflation; *cut.*, cuticle; *es.*, esophagus; *ex. p.*, excretory pore; *lab. p.*, labial papilla; *l. c. w.*, lateral cuticular wings; *n. r.*, nerve ring; *ph.*, pharynx. $\times 150$. (Original.)

The spiral of the caudal end of the male appeared in a few cases as a single coil like that of *Arduenna strongylina*. In other cases it consisted of an irregular double twist (fig. 28). In the greater number of specimens examined, however, it formed a broad open spiral like a corkscrew (fig. 19). Comparing the spiral to the thread of a screw, and considering the tip of the tail as the point of the screw, the spiral resembles a left-handed screw with three (rarely four) threads; no cases were seen in which the spiral revolved in the opposite direction.

The bursal wings are described as symmetrical by Railliet and Henry (1911b) and are so depicted by Von Drasche (1884a). The right wing is, however, a little longer than the left wing (fig. 19). Ciurea (1912) considers that it is also narrower, but this statement could not be verified by the present writer. Ciurea (1912) states that the bursal wings extend throughout the twisted portion of the tail. As seen by the present writer they extend only about half this distance (fig. 19). The cuticle on the ventral side of the male (fig. 19), commencing at some distance anterior of the spiral, is marked with longitudinal striations intercepted by transverse lines, appearing under high power as longitudinal folds of the cuticle separated by transverse ridges. A similar structure has already been noted on the ventral surface of *Arduenna strongylina* (fig. 2). As in most nematodes, the papillæ are arranged symmetrically on either side of the median line. Their grouping and structure have already been discussed.

The intestine is much convoluted, growing broader close to the cloaca. The vesicula seminalis occupies most of the body cavity in the posterior end, maintaining a fairly uniform diameter until it disappears dorsal of the intestine which conceals the ductus ejaculatorius. The long convoluted testis which extends to the middle of the body presents no specific characteristic features. The anus is

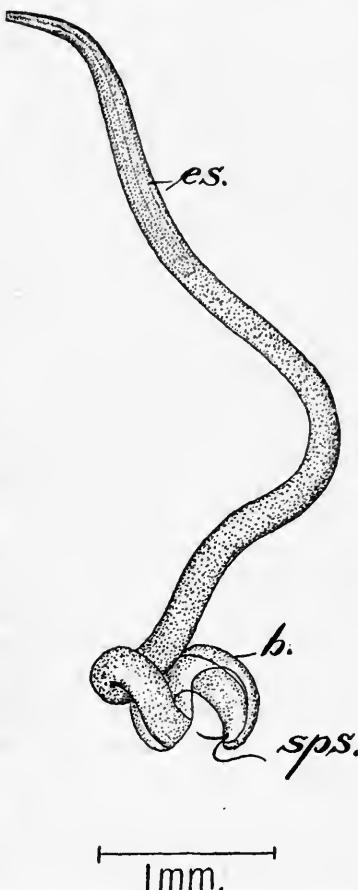


FIG. 28.—*Phyocephalus sexalatus*. General view of body of male. *b.*, bursa; *es.*, esophagus; *sp.s.*, spicules. $\times 23$. (Original.)

circular, like that of *Arduenna strongylina*, but not surrounded by a serrated ring.

The vulva (35 μ in diameter), as in *Arduenna strongylina*, apparently occupies a somewhat lateral rather than ventral position, opening toward the right side (fig. 22). It is situated just below the middle of the body, dividing the worm in the ratio of 9 to 8. According to Ciurea (1912) the cuticle in the region of the vulva is marked with longitudinal thickenings which may interlock with the cuticular ridges on the ventral surface of the male, and thus assist in maintaining the position of the male in copulation. The vagina, extending posteriorly along the right side, is at first 50 μ in diameter, but gradually broadens to 105 μ at its posterior end, where it disappears from the ventral side, extending dorsal of a lobe of the uterus. The distance from the vulva to this point is 976 μ . The wall of the vagina is relatively thick, composed of transverse muscle fibers. The lumen is 20 μ in diameter. Eggs containing well-developed embryos ready to pass out could be seen in single file in the lumen of the vagina near the opening (fig. 22). Railliet and Henry (1911b) describe the vulva as opening posteriorly at the limit of the third and four fifths of the body. Von Linstow (*in litt*) places it somewhat posterior of the middle of the body, dividing the worm in the ratio of 10 to 9.

The arrangement of the uteri and ovaries in the body of the female is, so far as could be seen, similar to that of *Arduenna strongylina*. The convoluted ovary of the posterior uterus occupies the caudal extremity of the worm, its terminus disappearing dorsal of the posterior uterus. A loop of the anterior uterus extends nearly to the caudal end. The exact length of the vagina was not determined. A loop of the posterior uterus, corresponding to the loop of the anterior uterus, lies underneath the anterior uterus and extends nearly to its terminus. The union of the vagina with the uteri was not seen, nor was the anterior ovary traced throughout its length. While neither uterus was followed throughout its entire length, the two termini, one posterior the other anterior, the posterior uterine loop, and the anterior loop, are all similar to the arrangement seen more clearly in *Arduenna strongylina*.

Ciurea (1912) depicts a pluglike protuberance at one of the poles of the eggs of *Phyocephalus sexalatus*, which bears a superficial resemblance to the operculum of a *Trichuris* egg, but does not penetrate the eggshell as in the latter case. This feature was not seen by the present writer; however, a faint transverse line could be seen at either pole (fig. 23), which apparently is the line of fissure along which the shell breaks when the embryo is liberated.

COMPARISON OF *PHYSOCEPHALUS SEXALATUS* AND *ARDUENNA STRONGYLINA*.

The following comparison of appearances of *Arduenna strongylina* and *Phyocephalus sexalatus* will assist in separating the two species without the aid of a magnifier.

Males.—Tail of *Phyocephalus sexalatus* ending in a spiral, *Arduenna strongylina* ending in a single coil; *Phyocephalus sexalatus* shorter and slenderer than *Arduenna strongylina*.

Females.—*Phyocephalus sexalatus* straight, or nearly so; specimens preserved in alcohol when lifted out of a petri dish with a needle bend sharply in the middle. Body slenderer than *Arduenna strongylina*, except toward the posterior end, which is thicker and blunter.

Alcohol specimens of *Arduenna strongylina* are usually curved in a half circle. They are thicker in the middle of the body than *Phyocephalus sexalatus* and pointed at both ends. On being lifted with a needle they do not collapse like *Phyocephalus sexalatus*, but maintain their crescentic shape.

As has already been stated, Molin (1860b) was the first to distinguish this species from *Arduenna strongylina*, with which it had been confused by Diesing (1851a). Besides the specimens from the white-lipped peccary, Molin (1860b) also found two females of this species in a bottle containing specimens of *Arduenna strongylina* collected by Bremser from the stomach of the wild boar and deposited in the Vienna Museum. That it has only twice been reported in Europe in association with *Arduenna strongylina* is perhaps due to confusion of the two species, an error which appears to have occurred in at least one case (Von Linstow, 1879b). In the United States it has been found in nearly every case in which specimens of *Arduenna strongylina* have been collected.

OTHER SPECIES REFERRED TO *PHYSOCEPHALUS SEXALATUS*.

Two other worms have been thought by different writers to be possibly identical with *Phyocephalus sexalatus*, viz., *Simondsia paradoxa* (Cobbond, 1864b) from *Sus scrofa domestica* and *Filaria nitidulans* (Schneider, 1866a) from *Tapirus americanus*.

Simondsia paradoxa was collected from the stomach of a German hog kept at Regent's Park, London, and was described by Cobbond (1864b). In a later work (1879b) Cobbond suggests the possibility of the worm being identical with *Phyocephalus sexalatus*. The immensely hypertrophied uterus of *Simondsia paradoxa*, forming a rosette entirely covering the caudal end of the female, however, clearly differentiates this species from *Phyocephalus sexalatus*.

In his description of *Phyocephalus*, Von Drasche (1884a) suggests the possibility that Schneider's (1866a) *Filaria nitidulans* may be identical with *P. sexalatus*. Both worms are characterized by three lateral wings on either side, and the caudal extremity of the males of both species are alike in the number and arrangement of the papillæ. The measurements of *Filaria nitidulans* (males 20 mm., females 32 mm.) are, however, far in excess of the measurements for *Phyocephalus sexalatus*, and the position of the vulva of *Filaria nitidulans* is stated as "directly above the anus," while the vulva of *Phyocephalus sexalatus* is slightly posterior of the middle of the body. Ciurea (1912), who has recently reexamined Schneider's material, was unable to determine the location of the vulva of *F. nitidulans*. He gives, however, a summary of the differences between *Filaria nitidulans* and *Phyocephalus sexalatus*, proving conclusively that they belong to different species, although he considers that *Filaria nitidulans* should be included in the genus *Phyocephalus*. Stossich (1897b), following Von Drasche's (1884a) suggestion, considered the worms identical. He listed *Tapirus americanus* as a host of *Phyocephalus sexalatus* and combined Molin's (1860b) measurements of *P. sexalatus* with Schneider's (1866a) measurements of *Filaria nitidulans*.

DISTRIBUTION OF ARDUENNA STRONGYLINA AND PHYOCEPHALUS SEXALATUS IN THE UNITED STATES.

Of nine lots of *Arduenna strongylina* collected in various parts of the United States and now deposited in the helminthological collection of the Bureau of Animal Industry, only two have been found not to contain examples of *Phyocephalus sexalatus*, and both of these lots contain only a few specimens. The distribution of *Arduenna strongylina* is therefore similar to that of *Phyocephalus sexalatus*, since the latter species, according to the writer's experience, is practically always associated with the former.

To determine the distribution of these parasites and the frequency of their occurrence in the United States the literature was searched for references to *Spiroptera strongylina*. Four such references were found, as below; in most cases *Phyocephalus sexalatus* was probably also present but not recognized.

1. Curtice (1892g), in a list of parasites infesting domestic animals and man in the United States, includes the following entry: "*Spiroptera strongylina* Rud. Host, *Sus scrofa domestica*. Location, stomach," followed by the remark, "Is often found with the food and attached to the walls." Specimens No. 2058 of the helminthological collection of the Bureau of Animal Industry were collected and identified by Curtice as *Spiroptera strongylina*. These specimens have been examined by the writer, who verified Dr. Curtice's identification. A few examples of *Phyocephalus sexalatus* were also present.

2. Stiles and Hassall (1894e) include *Spiroptera strongylina* in their preliminary catalogue of the parasites in the collection of the United States Bureau of Animal Industry. They report the parasite as common. The specimens referred to by them (No. 2057 of the bureau collection) have been reexamined by the writer, and many specimens of *Phyocephalus sexalatus* were found with the specimens of *Arduenna strongylina*. Stiles and Hassall's specimens were collected at Benning, D. C.

3. Francis (1894a) reported *Spiroptera strongylina* in a list of parasites collected by him in Brazos County, Tex. It is reported as common. The specific name is followed by an interrogation point in parenthesis to indicate the author's doubt as to the correctness of the identification. Considering the inaccuracy of the descriptions of *Arduenna strongylina*, then available, it is not to be wondered that Francis, noticing the discrepancies between the descriptions and the anatomical features seen in his specimens, should question the identification. On the other hand, it is quite possible that the specimens collected by Francis were *Phyocephalus sexalatus*, or included this species.

4. Kaupp (1910) reported the occurrence of *Spiroptera strongylina* in hogs raised in the Missouri Valley. His article is illustrated with original drawings, one of which shows the caudal end of the female with the vulva apparently on the right side, a little anterior of the anus.

For the sake of additional data, letters were sent to the inspectors in charge at some of the principal slaughterhouses of the United States, requesting information in regard to the occurrence of *Spiroptera strongylina* in hogs. Replies were received from South Omaha, Chicago, St. Louis, and Kansas City. The inspector in charge at South Omaha reported that fully 80 per cent of the hogs examined were infested. It was reported from St. Louis that "the worms occur in considerable numbers in the mucous coating of the stomach." The parasite is reported as very frequent in hogs slaughtered at Kansas City; out of 1,450 hogs examined, 1,052 were infested. In some stomachs as many as 140 worms were collected. From Chicago it was reported that 1,000 hogs had recently been examined, and 690 were found infested. The worms were found on the surface of the mucous membrane or attached by the head. Several hundred specimens obtained by scraping the mucosa from the stomachs of a number of infested hogs were received from this city. These worms were found to be *Arduenna strongylina* and *Phyocephalus sexalatus*.

Reports from slaughterhouses regarding the occurrence of parasites are of but little value in determining the localities infested by a given parasite, as the animals slaughtered are received from widely scattered sections of the country. Enough data have been gathered,

however, to warrant the assertion that the parasites occur throughout the middle and southwestern (and probably eastern) United States. Specimens have been collected by Hall in 1908 from a hog kept at Bethesda, Md., in all probability of eastern origin. They have also been collected by Kilborne at Washington, D. C., and by Stiles and Hassall at Benning, D. C.; in the latter case, however, it is possible that the host animal had been shipped to the local slaughterhouse from a Western or Central State.

RELATIVE FREQUENCY OF THE TWO SPECIES.

That *Physocephalus sexalatus* occurs less abundantly than *Arduenna strongylina* in American swine is indicated by the following data:

All the worms contained in a bottle of specimens forwarded from Chicago were sorted out by species and sex. The bottle contained 744 specimens. Of these, 599, or approximately 80 per cent, were *Arduenna strongylina*, and the remaining 145, or 20 per cent, were *Physocephalus sexalatus*. Of the 599 specimens of *Arduenna strongylina*, 399, or 56 per cent, were females, and 260, or 44 per cent, were males. A smaller percentage of males was found among the specimens of *Physocephalus sexalatus*. Of the 145 specimens found, 69 per cent were females and 31 per cent were males.

LESIONS ASSOCIATED WITH ARDUENNA STRONGYLINA, ARDUENNA DENTATA, AND PHYSOCEPHALUS SEXALATUS.

From an economic standpoint these three species are probably of considerable importance. Prior to 1899 it was not considered that *Arduenna strongylina* was especially injurious to swine. Neumann (1892a), in mentioning that *Spiroptera strongylina* caused small submucous tumors of the stomach and that no morbid disturbances were attributed to it, summed up the general opinion of the time regarding the economic importance of the parasite. More recent reports, however, indicate that these parasites should be regarded as the possible etiology of serious gastric disorders.

Von Rátz (1899d) found *Spiroptera strongylina* very common among swine in Hungary, and attributed to this parasite several epizootics of a rather serious nature, in one of which, out of a herd of 230 sows, 21 were seriously affected and 6 died. Some of the symptoms were described as follows:

The diseased sows suffered from loss of appetite, eating very little and in the worst cases finally refusing all food; on the other hand, they drank water excessively and were very restless, continually pawing the ground.

Describing the post-mortem lesions seen in the stomach, Von Rátz says:

At the pyloric end the mucous membrane was covered with a thick, lamellous, firmly adhering pseudomembrane, which upon being removed revealed a superficial loss of tissue of the mucous membrane. Under the mucous membrane lay numerous

Spiroptera strongylina fastened partly in the stomach wall, partly in the pseudo-membrane. In addition to these lesions, dark red spots the size of a penny were to be seen, corresponding to which were numerous openings the size of a needle prick, through which projected the bodies of the nematodes.

While no data are at hand regarding the effect of *Arduenna dentata* on its host, in view of its close similarity with *Arduenna strongylina* and the fact that both species are parasitic in the stomach, it may be assumed that the former species is as injurious as the latter.

Railliet and Henry (1911b) report that the stomach of a sow from Madagascar from which specimens of *Phyocephalus* were collected, presented a very intense gastritis with a quantity of small elevations on the mucosa.

The information and material supplied by the inspectors of this bureau have shown that lesions of a nature similar to those described by Von Rätz are frequently associated with the presence of *Arduenna strongylina* in this country.

The inspector in charge at South Omaha reported that "Ten per cent of the affected stomachs show a highly inflamed zone surrounding the infested area, and in a few instances considerable ulceration exists." The inspector in charge at St. Louis was of the opinion that "they produce no apparent lesions." The inspector in charge at Chicago forwarded, in addition to the loose specimens already mentioned, several pieces of hogs' stomachs showing the worms in situ. The heaviest infestations were found in portions from the pyloric end of the stomach, which in one instance presented the following appearances: A piece of stomach from the pyloric end about 21 cm. wide by 20 cm. long contained a cluster of worms buried in a glairy mucous mass of yellowish color firmly attached to the normal mucous membrane, and forming, in the opinion of pathologists in the Pathological Division of this bureau, to whom the tissues were referred, a pseudomembrane of necrotic tissue. Several such worm clusters were observed on the portion examined, the worms in nearly every case being buried in a mass of mucus, and appearing as bright red lines in the yellowish mass. (See Pl. I.) In places the necrotic tissue had apparently sloughed off, leaving deep, red, depressed areas of irregular shape. These areas varied in size from a few millimeters to 2 or 3 centimeters in diameter. The same lesions could be observed under the necrotic tissue when this had been removed with forceps. The condition was described by one of the pathologists as "undoubtedly ulcerous."

It was suggested by the pathologists who examined the material that the pseudomembranes might have been caused by *Bacillus necrophorus* gaining an entrance to the submucosa as the result of the piercing of the mucous membrane by the parasitic worms; examinations of scrapings from the stomach lesions revealed a few specimens of the bacillus. As explained by Mohler and Morse (1904), this

bacillus is normally found in the stomachs of hogs and other animals, and while under ordinary circumstances it has no pathological effect, if enabled through some lesion to the mucous membrane to gain access to impaired tissue, its proliferation results in the sloughing of the mucous membrane and the formation of ulcers.

Mohler and Morse (1904), describing necrobacillosis of the digestive tract, state: "The necropsy in such cases revealed hemorrhages and erosions in the stomach, but no areas of coagulation," an accurate description of the conditions found by the present writer. The characteristic odor described for lesions of *Bacillus necrophorus* was only faintly present, being modified perhaps by the boric acid with which the specimen was sprinkled and which may account for the paucity of the parasitic flora found.

How deeply *Arduenna strongylina* is capable of penetrating into the submucosa was well shown in one of the specimens forwarded from Chicago. A piece of the cardiac portion of the stomach contained a worm 12 mm. long which had bored diagonally into the mucosa to a depth of 10 mm., only the caudal end projecting above the surface. The hole made was similar to a pin prick, a simile used by Von Rätz (1899d) in describing the lesions observed by him. Indeed Von Rätz's description is practically identical with the conditions found by the present writer.

The habit of boring into the mucosa characteristic of these parasites would seem an ideal method of inoculating the submucosa of the host with *Bacillus necrophorus* if any were present, and this, considered in connection with the conditions observed in infested stomachs, indicates that the worms may be the indirect cause of grave ulceration. Considered apart from their possible rôle as infective agents, the mechanical injury to the stomach walls due to the penetration of the worms in numbers would seem to be a serious factor even if the worms were unassociated with bacilli. Moreover, the livid red color of the worms in situ in the stomachs examined would seem to indicate that they feed on blood, an additional reason for regarding them as dangerous parasites. The whole question, however, of the pathogenicity of the parasites, and as to their relationship to the lesions observed, remains open for further investigation.

An examination of the stomach portions received showed specimens of *Phyocephalus sexalatus* attached in the same manner as already noted for *Arduenna strongylina*; hence the former parasite may be considered only less dangerous than the latter, as it is less abundant.

LIFE HISTORY.

Nothing is known in regard to the development of the worms from the egg to the adult. The wide distribution, the frequency of the parasites, and the similarity of the eggshell to that of an ascarid,

suggest the possibility that development occurs without an intermediate host. From the fact that the embryos are well developed in the uterus before oviposition, it would seem that but little time is required for incubation, and the thickness of the shell would indicate the necessity of the gastric juice of the host to dissolve the shell and liberate the embryo.

PREVENTIVE MEASURES.

In the absence of knowledge as to the life cycle of the parasites, no prophylaxis or treatment specially adapted to the case can be formulated. The following general prophylactic measures are suggested:

1. Hogs suffering from loss of appetite or failing to fatten under proper food and hygiene should be examined for evidence of infection by killing one or two and looking in the stomach for worms; or, where practicable, the feces of the entire herd may be examined microscopically.
2. Those swine found infested with stomach worms should be isolated from noninfested or presumably noninfested swine in clean pens, and the dung removed daily and mixed with quicklime or disposed of by carting it to places to which hogs do not have access.
3. The noninfested swine should not be allowed to remain in the same pens formerly occupied by the infested animals, but should have clean quarters. The old pens should be thoroughly disinfected with lime after removing the dung and burning over the ground where feasible.

MEDICINAL TREATMENT.

Youatt (1847c), referring to *Spiroptera strongylina*, recommends turpentine and salt with the food for treating these worms. Coal-tar creosote, gasoline, and copper sulphate have been found more or less efficacious in treating stomach worms (*Hæmonchus contortus*) in sheep, and similar treatment might be tried on pigs (see Bureau of Animal Industry Circular 102). Santonin and calomel, 3 grains each per hundred pounds of body weight, given after a fast of 12 to 16 hours, is another remedy which deserves trial.

Whatever drug is used should first be given in small quantities and tried on a few of the most heavily infested swine, the size of the dose being increased as occasion demands.

KEY TO THE ROUNDWORMS PARASITIC IN DOMESTIC SWINE.

The arrangement of the following key to the roundworms which have been reported by various authors as parasites of hogs is purely artificial and arbitrary and indicates nothing as to the systematic relationship of the different forms. A classified list of the roundworms of swine is given later on page 41.

	Section.
Parasitic in alimentary tract.....	1
Parasitic in respiratory tract.....	16
Parasitic in other organs.....	17
1. Diameter of body at middle over 3 mm.....	2
Diameter of body at middle less than 3 mm.....	3
2. Anterior extremity furnished with a protractile proboscis covered with spines.	
Male 6 to 10 cm. long, 3 to 5 mm. in diameter. Female 20 to 35 cm. long, 4 to 9 mm. in diameter. Eggs, 87 to 100 μ long, subcylindrical, smooth, with 3 envelopes. In small intestine, usually attached to the mucous membrane.....	<i>Gigantorhynchus hirudinaceus.</i>
Anterior extremity without protractile proboscis. Mouth with 3 prominent lips. Male 15 to 17 cm. long, 3 to 3.2 mm. thick. Female 20 to 25 cm. long, 5 to 5.5 mm. thick. Eggs oval, 66 μ long, thick-shelled, surface covered with mammillate projections. In small intestine, sometimes in biliary tract and pancreas.....	<i>Ascaris suum.</i>
3. Less than 5 mm. in length.....	4
Over 5 mm. in length.....	5
4. Vulva anterior of middle of body. Ovoviparous. Females 3 to 4 mm. long, 60 μ in diameter. Males 1.4 to 1.6 mm. long, 40 μ in diameter, with a short finger-like process on each side of the anal opening. Adults in small intestine, larvæ encysted in skeletal muscles.....	<i>Trichinella spiralis.</i>
Vulva posterior of middle of body. Females (parthenogenetic; parasitic males lacking) 3.75 mm. long, 80 μ in diameter. Eggs 45 μ long by 25 μ broad, with thin shells. In small intestine.....	<i>Strongyloides suis.</i> ¹
5. Head covered with spines; separated from the body by a deep constriction.	
Male 15 to 25 mm. long. Female 22 to 31 mm. long. Eggs 70 μ long by 39 μ wide. In stomach.....	<i>Gnathostoma hispidum.</i>
Head without spiny armature.....	6
6. Posterior end of body of female with relatively large rosette-like excrescence containing the hypertrophied uterus. Male 12 mm. long. Female 15 mm. long. In stomach.....	<i>Simondsia paradoxa.</i> ²
Posterior end of body of female without uterine rosette.....	7
7. Anterior portion of body slender, like a whiplash, about twice as long as the thicker posterior portion. Male with single spicule. Male 33 to 40 mm. long. Female 34 to 50 mm. long. Eggs 52 to 56 μ long, ellipsoidal, with an opening at each pole closed by a plug-like operculum, and brownish in color. In cecum.....	<i>Trichuris suis.</i>
Body continuous, not flagelliform anteriorly. Male with two spicules.....	8

¹ While *Strongyloides papilliferus* (= *Trichosoma papilliferum* Wedl.) a parasite of sheep has frequently been reported for the pig, this is probably the result of confusion with *Strongyloides suis*. The *Strongyloides* of the pig is somewhat larger than the form found in sheep.

² Included by the present writer among the Filariidae on account of the inequality of the spicules. Its position in this family is not, however, definitely established. See footnote on page 9, second paragraph.

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8. Male with two equal or subequal spicules; tail with membranous bursa supported by paired rays and eggs with thin shells.....	9
Male with two spicules of very unequal length; tail with lateral longitudinal bursal membranes supported by stalked papillæ. Eggs with thin or thick shells.....	12
9. Mouth enlarged to form a buccal capsule.....	10
Mouth small; buccal capsule not present. Male 5 mm. long. Female 8 to 8.5 mm. long. Spicules 130 μ long. Vulva about 2 mm. from the tip of the tail. Eggs, 45 μ long by 36 μ wide. In stomach.....	" <i>Strongylus</i> " <i>rubidus</i> . ¹
10. Buccal capsule broader than long, mouth bordered by a crown of numerous, small, pointed processes. Male 8 to 12 mm. long. Female 12 to 15 mm. long. Spicules slender, 1.13 mm. long. Vulva a short distance in front of anus, protuberant. Adults in large intestine, larvæ encysted in the wall of the large and small intestines, forming nodules. <i>Æcospagostomum dentatum</i> . Buccal capsule spherical or elongated, border of mouth smooth.....	12
11. Buccal capsule spherical. Male 7 mm. long, 0.2 mm. thick. Female 8 mm. long, 0.3 mm. thick. Vulva prominent. In small intestine.	
<i>Globocephalus longemucronatus</i> . Buccal capsule elongated, oval. Male 4.4 mm. long, 0.38 mm. thick. Female 6.5 mm. long, 0.52 mm. thick. Spicules 590 μ long. Vulva sunken. In small intestine.....	
12. Anterior end of body supplied with numerous cuticular tubercles or shields. Anterior end of body without cuticular tubercles.....	13
13. Male 30 to 50 mm. long by about 250 μ thick. Female 80 to 145 mm. long, 300 to 350 μ thick. Left spicule 16 to 17 mm. long; right spicule 140 to 180 μ long. Vulva 4 to 5 mm. from tip of the tail. Eggs 55 to 60 μ long by 32 to 36 μ wide. In the mucosa of the esophagus and pharynx.	
<i>Gongylonema scutatum</i> . ² Male 14 to 50 mm. long, 175 to 195 μ thick. Female 37 to 40 mm. long (?) or longer, 350 μ thick. Left spicule 4 to 5 mm. long, right spicule 84 to 110 μ long. Vulva about 2 mm. from the tip of the tail. Eggs 52 to 56 μ long by 32 μ wide. In the mucosa of the esophagus and pharynx.	
14. Body furnished anteriorly with six longitudinal lateral wings, three on each side, the middle wing of each three wider than the other two. Ridges of pharynx forming a simple spiral, breaking up into separate wings. Male 6 to 9 mm. long. Female 13 to 19 mm. long. Spicules 2.1 to 2.25 mm. long, and 300 to 350 μ long, respectively. Vulva anterior of the middle of the body. Eggs 34 μ long by 15 μ wide, with rather thick shells. In stomach.	
<i>Gongylonema pulchrum</i> . Anterior portion of body with a single longitudinal wing. Ridges of pharynx forming a continuous multiple spiral.....	15

¹ "*Strongylus*" *rubidus* does not belong in the genus *Strongylus*. Its proper position is in the family Trichostrongylinæ. As yet, however, no genus has been established to which it may be assigned.

² Reported by Korzil (1877a) and Piana (1896b). According to Neumann (1894d), however, the measurements given by Korzil indicate that the species studied by him is *Gongylonema pulchrum*, Molin 1857. The measurements given by Piana (1896b) are, males 60 to 80 mm. long by 130 μ broad; females 80 to 145 mm. long, 600 μ broad. Except that *G. pulchrum* is smaller than *G. scutatum*, there is but little morphological difference between the two species. The species are considered identical by Railliet (1893a), although this view is not accepted by Neumann (1894d) and others. *G. scutatum* is normally a parasite of ruminants.

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15. Male 10 to 15 mm. long. Female 16 to 22 mm. long. Long spicule 2.24 to 2.95 mm. in length, 5 to 6 times as long as the short spicule. Vulva somewhat anterior of the middle of the body. Eggs 34 to 39 μ long by 20 μ wide, with rather thick shells. In stomach. *Arduenna strongylina*.
 Male 25 to 35 mm. long, 700 to 800 μ broad. Female 40 to 55 mm. long, 1.1 to 1.2 mm. broad. Long spicule 3.75 to 4.23 mm. long. Short spicule 540 to 650 μ long. Vulva three-eighths of the distance from the anterior end.
 *Arduenna dentata*.

16.¹ Spicules about 4 mm. long, each terminated by a single hook. Vagina about 2 mm. long. Male between 12 and 25 mm. in length. Female between 20 and 50 mm. in length. Vulva near anus. Eggs between 57 and 100 μ in length and 39 and 73 μ in width. In trachea and bronchi. *Metastrongylus apri*.
 Spicules 1.5 mm. long, each terminated by a double hook. Vagina about 500 μ long. Male between 12 and 25 mm. in length. Female between 20 and 50 mm. in length. Vulva near anus. Eggs between 57 and 100 μ in length and 39 and 72 μ in width. In trachea and bronchi.
 *Metastrongylus brevivaginatus*.

17.² Encysted in skeletal muscles, microscopic in size. Cysts slightly elongated, ovoid, long axis parallel to the muscle fibers, about 400 μ long by 250 μ broad.
 *Trichinella spiralis* (larvae).
 Free in peritoneal cavity, in kidneys, in ureters, in the bladder, or encysted in fat of kidneys or loins. 18

18. Male under 40 mm. long. 19
 Male over 12 cm. long. 20

19. Male 25 to 37 mm. long. Female 37 to 40 mm. long. Two spicules, equal or subequal, about 0.8 mm. long. Vulva less than 2 mm. from the tip of the tail. Eggs 100 μ long by 56 μ wide, with thin shells. In kidneys, ureters, and encysted in fat of kidneys and loins. *Stephanurus dentatus*.

20. Male 14 to 40 cm. long, 4 to 6 mm. in diameter. Female 20 cm. to 1 m. long, 5 to 12 mm. in diameter. Spicule single, 5 to 6 mm. long. Vulva near the anterior end of the body. Eggs 64 to 68 μ long by 40 to 44 μ wide, thick-shelled, with pitted surface. In kidneys, ureters, peritoneal cavity, or bladder. *Diocophyllum viscerale*.³
 Male 10 to 11 cm. Greatest diameter, 650 μ . Tail twisted in a loose spiral with a pointed end; 8 pairs of papillæ, 4 preanal and 4 postanal. Spicules unequal, the longer 215 μ long, 25 μ broad, with a membranous extension 70 μ long. Short spicule 140 μ long, 52 μ broad. Female 20 to 21 cm. long. Vulva 600 μ from the anterior extremity. Anus 300 μ from the posterior extremity. Eggs ovoid, 45 by 26 μ when fully developed. Viviparous. Parasitic in the peritoneal cavity. *Setaria bernardi*.

¹ Railliet and Henry, 1911, describe a new species, *Filaria bouchei*, found in the "lungs" of a hog slaughtered at Hué, Indo-China. The location of the parasite is not definitely known. The female alone was found. It is reported as 22½ cm. long, with a maximum diameter of 635 μ . The body is transversely striated, the striae being 5 to 6 μ apart. Mouth unarmed, funnel-shaped, the cuticle thickened at the anterior end. Anus 155 μ from the posterior extremity; vulva 1.1 mm. from the mouth.

² *Gigantorhynchus hirudinaceus*, although normally located in the intestine, sometimes perforates the intestinal wall, in which case it may be found in the peritoneal cavity. (See No. 2 of this key, first paragraph.)

Ascaris suum may be found aberrant in various locations outside the digestive tract. Diagnostic characters for the identification of this species have already been given. (See No. 2 of this key, second paragraph.)

³ Included by Von Linstow (1878a) among the parasites of the domestic hog, but its occurrence in this host is questionable.

CLASSIFIED LIST OF ROUNDWORMS PARASITIC IN DOMESTIC SWINE.

Specific descriptions are omitted from the following list as these have already been given in the key to the roundworms of swine. Arranged according to their respective orders, families, and genera, the roundworms reported as parasitic in domestic swine are as follows:

Class Nemathelminthes: Cylindrical worms without a prebuccal ciliary apparatus provided with a variable nervous system, not forming a ventral chain. Generally dioecious.

Order Nematoda. Nemathelminthes: Provided with a complete digestive tube.

Family Angiostomidae. Nematoda: Having two heterogenetic generations, one of free-living males and females and one of hermaphroditic or parthenogenetic forms which are parasitic.

Genus *Strongyloides*. Angiostomidae: Parasitic form with mouth opening directly into the relatively very long subcylindrical esophagus. Vulva posterior of the middle of the body. Uterus double. Two ovaries. Free-living form with mouth opening into a vestibule or pharynx, followed by an esophagus whose anterior portion is fusiform and posterior portion globular.

Strongyloides suis.

Family Gnathostomidae. Nematoda: Body furnished throughout its length, or only anteriorly, with chitinous blades or wings, serrated posteriorly. Head subglobular, covered with simple spines.

Genus *Gnathostoma*: With the characteristics of the family.

Gnathostoma hispidum.

Family Trichinellidae. Nematoda: Esophagus consisting of a chain of single cells, the lumen of the esophagus passing through the center of each cell. Anterior portion of body containing the esophagus usually very slender; posterior portion containing the intestine and reproductive organs more or less swollen. One testicle, one ovary.

Subfamily Trichinellinae. Trichinellidae: Male without spicule. Female ovoviviparous. Adults in intestine of host produce larvae which penetrate into the muscles, become encysted, and develop to maturity when the flesh of this animal is eaten by another animal.

Genus *Trichinella*. Trichinellinae: Very small worms with capillary bodies. Progressively increasing in diameter posteriorly. Male with two conical posterior appendages forming a copulatory bursa. Vulva of the female in the anterior fifth part of the body.

Trichinella spiralis.

Subfamily Trichurinae. Trichinellidae: Male with spicule. Female deposits eggs characterized by the presence of an opening at each pole closed by a pluglike operculum. Eggs do not hatch until swallowed by a suitable host. Development, so far as is known, direct, without an intermediate host.

Genus *Trichuris*. Trichurinae: Anterior portion of body very long and slender. Posterior portion of body containing the intestine and reproductive organs relatively thick and much shorter than the anterior portion. Posterior portion of male rolled dorsally into a spiral. Spicule surrounded by a prepuce-like sheath. Posterior portion of body of female slightly curved. Vulva near the beginning of the posterior portion of body..... *Trichuris suis.*

Family Filariidæ. Nematoda: Body long, filiform. Mouth surrounded with papillæ, or provided with two lips. Esophagus slender, without posterior bulb. Males with two unequal spicules (sometimes with a single spicule). Females with two ovaries. Vulva usually anterior of the middle of the body. Development often requires an intermediate host.

Genus *Filaria*. Filariidæ: Body long and slender, of nearly uniform diameter throughout; males considerably smaller than the females, with the tail hooked or curved in a spiral, sometimes furnished with lateral wings. Usually there are four preanal and a variable number of postanal papillæ. Spicules usually very different in shape and dimensions. Vulva more or less near the mouth.

Filaria bauchei.¹

Genus *Setaria*. Filariidæ: Head armed with a projecting peribuccal circle, deeply notched laterally, somewhat less indented dorso-ventrally, giving the impression of two teeth when seen laterally and of four teeth when seen at an angle. Tail of both sexes provided with two special appendices.....*Setaria bernardi*.

Genus *Gongylonema*. Filariidæ: Body filiform, slightly attenuated at either end. Anterior portion of body covered with numerous tubercles or shields formed by differentiation of the cuticle. In the median lines immediately behind the mouth, two semilunar depressions, one dorsal, the other ventral. Tail of male curved ventrally, supplied with two asymmetrical membranous wings. Vulva a short distance anterior of the anus. *Gongylonema scutatum*.²

Gongylonema pulchrum.

Subfamily Arduenninæ. Filariidæ:³ Mouth with two lateral lips leading into a pharynx marked with cuticular ridges in the form of spirals or rings. Spicules unequal, the longer several times the length of the shorter. Four pairs of preanal papillæ. Eggs containing embryos at the moment of oviposition.

Genus *Arduenna*. Arduenninæ: Mouth leading into a cylindrical pharynx marked by ridges, forming a continuous multiple spiral. Esophagus continuous, nearly one-third of the length of the body. Spicules very long and very unequal. Tail twisted in a single coil. Bursa asymmetrical, supported by five pairs of papillæ.

Arduenna strongylina.

Arduenna dentata.

Genus *Phyocephalus*. Arduenninæ: Body furnished anteriorly with six lateral wings arranged in a group of three wings each, on either side. The middle wing of each group is the widest. Pharynx cylindrical, relatively broad and long, marked with a simple spiral ridge on the inside, breaking up into separate rings and resuming the spiral at the posterior end.....*Phyocephalus sexalatus*.

Genus *Simondsia*.⁴ Filariidæ: Female characterized by a tegumentary excrescence in the form of a rosette situated in the posterior part of the body and inclosing a prolongation of the intestine and a hypertrophied uterus.....*Simondsia paradoxa*.

¹ This species, described by Railliet and Henry (1911), is provisionally included in the genus *Filaria*, *sensu lato*. As only one female was received, the material was insufficient for a more accurate generic diagnosis.

² See footnote 2, p. 39.

³ See footnote, p. 9.

⁴ Railliet and Henry (1911b) include *Simondsia* in the subfamily Arduenninæ, although Piana (1897) describes the lips as dorso-ventral rather than lateral. In the structure of the esophagus, the number of preanal papillæ, and the inequality of the spicules *Simondsia* conforms to the description of the subfamily Arduenninæ.

Family Strongylidae. Nematoda: Head with six more or less distinct circumoral papillæ. Males with a more or less well-developed bursa, each lateral lobe of which is usually supplied with six supporting rays. Spicules equal or subequal. Vulva may be anterior to the middle of the body, but is usually posterior. Oviparous. Development, so far as known, direct without intermediate host.

Subfamily Strongylinae. Strongylidae: Buccal capsule well developed. Eggs in the process of segmentation at the moment of oviposition. Embryo nearly always rhabditiform and development direct. Parasitic in the alimentary canal; exceptionally in the respiratory system.

Genus *Esophagostomum*. Strongylinæ: Head 75 μ or more in diameter; buccal capsule small. Cuticle surrounding the mouth usually inflated to form a ringlike mouth collar. Bursa of male with two lateral lobes united by a smaller median lobe. Spicules more than 0.5 mm. long, slender, tubular, pointed; gubernaculum present, but not conspicuous. *Esophagostomum dentatum*.

Genus *Globocephalus*. Strongylinæ: Buccal capsule cylindrical, larger in diameter than the thickness of the body, supported by two chitinous rings—one at the anterior end of the capsule, the other at the posterior end. The rings are joined by four chitinous longitudinal bands. *Globocephalus longemucronatus*.

Genus *Crassisoma*. Strongylinae: Buccal capsule oval, smaller in diameter than the thickness of the body, supported by eight longitudinal thickenings of the cuticle, and a chitinous ring on the inside of the capsule. *Crassisoma urosubulatum*.

Subfamily Trichostrongylinae. Strongylidae: Buccal capsule absent or slightly developed. Eggs generally segmenting at the time of oviposition. Embryo rhabditiform and development direct. Parasitic in the alimentary canal.

Genus. Undetermined¹ *Strongylus rubidus*.

Subfamily Metastrongylinae: Strongylidae: Buccal capsule absent or slightly developed. Eggs in various stages when oviposited. Embryo rhabditiform. Evolution unknown, perhaps requiring an intermediate host. Parasites of the respiratory or circulatory system.

Genus *Metastrongylus*. Metastrongylinæ: Mouth with six lips. Postero-lateral ray much reduced or absent. Dorsal ray and externo-dorsal rays slender, the others thick. Two very long spicules. Vulva close to the anus. Eggs with well-developed embryos. Parasitic in the bronchi and trachea.

Metastrongylus apri.

Metastrongylus brevivaginatus.

Subfamily not determined.

Genus *Stephanurus*. Strongylidae: Anterior extremity truncated; mouth suborbicular, limited by a chitinous ring furnished with teeth. Caudal bursa of male with many lobes.

Stephanurus dentatus.

¹ See footnote 1 on p. 39.

Family not determined.¹

Genus *Dioctophyme*. Nematoda: Body cylindrical, mouth without lips, surrounded by papillæ. Male furnished with a filiform spicule. Female with a single ovary. Vulva in the anterior part of the body..... *Dictophyme visceralis*.

Family *Ascaridæ*. Nematoda: One lip median, dorsal; two submedian, ventral. Relatively thick forms. Males provided with two spicules. Females with double ovary.

Genus *Ascaris*. *Ascaridæ*: Furnished with three strong lips, the lateral sides of which are generally toothed. Males with two equal or subequal spicules and numerous papillæ anterior and posterior of the anus. Vulva located anterior of the middle of the body. Eggs globular or ellipsoidal, usually surrounded by an albuminous envelope. In process of segmentation at the time of oviposition *Ascaris suum*.

Order *Acanthocephala*. Nemathelminthes without mouth or digestive tube. Furnished with a protractile proboscis armed with hooks.

Family *Gigantorhynchidæ*. *Acanthocephala*: Body large and annulated; tæniaform. Hooks of the proboscis with two roots and covered with a transparent layer of chitin. Lemnisci lengthened into the form of rounded bags and having a central canal.

Genus *Gigantorhynchus*; with the characteristics of the family.

Gigantorhynchus hirudinaceus.

¹ *Dictophyme visceralis* although commonly included in the family *Strongylidæ* does not conform to all the characteristics of this family. It more closely resembles the *Filariidæ* as pointed out by Raillet and Henry (1909a). Probably it should be placed in a family by itself, but the question is open to further study.

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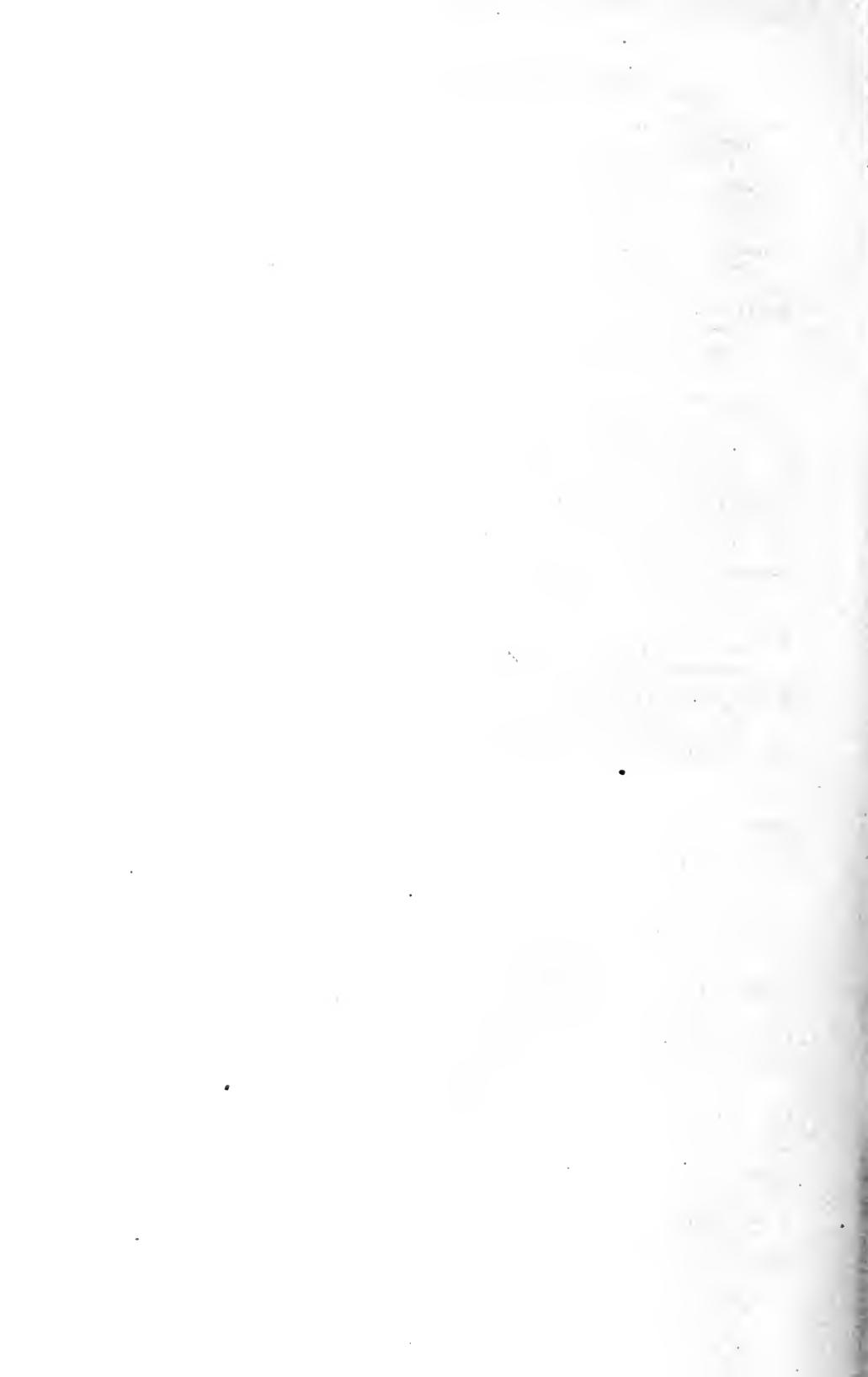
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